CHAPTER 1
ANNUAL PROGRAM SUMMARY

Jean Watson
FAA Office of Aviation Medicine

William Johnson
Galaxy Scientific Corporation

1.1 EXECUTIVE SUMMARY

The Office of Aviation Medicine, once again, offers the annual detailed reports on each of the research and development projects. These reports are products of the Human Factors in Aviation Maintenance and Inspection research program. All of the Program's eleven years are documented on the Federal Aviation Administration (FAA) website (or directly at www.hfskyway.com). The first ten years of research are available on CD-ROM through the FAA Office of Aviation Medicine or Galaxy Scientific Corporation in Atlanta, Georgia. The FAA Program Manager and the research team are particularly proud that all written products of over a decade of research are readily accessible. This capability is representative of the manner in which the research focused on enhancing human performance by application of technology.

Requirements or suggestions from the White House, government safety committees, the National Transportation Safety Board (NTSB), and the industry representative groups drive much of the year's research. This direction is consistent with the applied nature of the program since its inception in 1988. This summary shall briefly review each of the eleven chapters and four individual research reports.

1.2 CHAPTER SUMMARIES

1.2.1 Chapter 2: Maintenance Error Causation

Chapter 2, written by David Marx , entitled *Maintenance Error Causation*, is a multifaceted research report. This research report covers aspects of human maintenance error in an attempt to determine the appropriate depth of an investigation of error. Secondly the research reports the results of an extensive maintenance error survey. Over 200 industry personnel responded to a survey assessing how they conducted error investigations. The survey tested six hypotheses regarding individual investigative style. Finally, the research offers and describes seven rules of causation that can guide human error investigations in maintenance organizations.

1.2.2 Chapter 3: Improving Operations and Oversight of Contract Maintenance

Raymond Goldsby of Galaxy Scientific Corporation writes Chapter 3. This research project report* is a result of accidents and incidents like ValuJet. The study is a result of extensive visits and discussions with personnel from U.S. repair stations and FAA field offices. In seven geographical locations over 60 personnel were interviewed. The research shows that there have been extensive improvements to the repair station system since the U.S. Government Accounting Office Report of 1997. The repair station regulatory oversight and cooperation is working well to ensure compliance and safety. The research identifies opportunities for improvement associated with FAA rulemaking, communication, and standardization of oversight across FAA geographical regions. The report ends each section with numerous direct quotes from both industry and FAA personnel. The report concludes with eight recommendations to ensure and improve the repair station system.

1.2.3 Chapter 4: Use of Computer-Based Training for Aircraft Inspection: Minimizing Errors and Standardizing the Inspection Process

Anand Gramopadhye and his colleagues from Clemson University author Chapter 4. This research project report describes the development and functionality of the Automated System of Self-Instruction for Specialized Training (ASSIST). The software is an interactive simulation that permits a variety of visual inspection tasks. The software includes routines to track student performance and also to modify training scenarios. Since the primary deliverable is the software, the report is purposely brief. The 2-CD-ROM set of ASSIST is available through www.hfskyway.com .

1.2.4 Chapter 5: An Assessment of Industry Use of FAA Human Factors Research from 1988 through 1998

Ms. Jean Watson of the FAA Office of Aviation Medicine and Dr. William B. Johnson of Galaxy Scientific write Chapter 5. This research report, published in mid-1998, is the result of a sampling to 122 respondents from the aviation maintenance industry worldwide. The results show that the industry is very familiar with the research program and is using the research technical information and products. The program receives high marks, as described in detail throughout the report. Of particular interest is the Appendix containing a multitude of open-ended comments.

1.2.5 Chapter 6: Standardizing the Shift Change Process: Efforts to Minimize Shift Change Errors

Anand Gramopadhye and colleagues at Clemson University write Chapter 6. Shift change has been widely reported as a cause of several errors/accidents in the aircraft maintenance industry. This can be attributed to a lack of well-defined shift change procedures for use by the aircraft maintenance industry. In response to this need, industry has developed ad-hoc measures and general guidelines to assist various personnel involved in the shift change process. This research looked at the entire shift change process at representative aircraft maintenance sites. Following a detailed task analysis of the shift change process, taxonomy of errors was developed. The analysis focused on communication norms, shift change procedures, guidelines, and existing mandated procedures. The analysis along with the taxonomy of errors was used to identify human factor interventions to develop a standardized shift change process that minimizes shift change errors.

1.2.6 Chapter 7: Standards for Certification of Aviation Maintenance Technician Training Program Using the AMT/AMT-T Integrated Curriculum

Chapter 7 is written by Charles White of Aviation Training and Technical Consulting and Professor Mike Kroes of Purdue University. This research report gives the results of a survey completed by 75 aviation maintenance training institutions. The respondents were not satisfied with the ability of the current regulatory system to measure quality or to encourage curricula upgrade. The report outlines suggestions to upgrade current curricula to meet the occupational requirements for airline maintenance. The research addresses a variety of issues including, but not limited to, curricula, course sequencing, faculty, class size, professional development, testing, facilities, and more.

1.2.7 Chapter 8: Human Factors Accidents Classification System Analysis of Selected NTSB Maintenance-Related Mishaps

CDR John K. Schmidt of the Naval Postgraduate School writes Chapter 8. This research project capitalizes on an FAA database of NTSB accidents that resides on the FAA (www.hfskway.com) website and on numerous CD-ROMs distributed by the FAA Office of Aviation Medicine. Dr.

Schmidt uses the Naval Safety Center's Human Factors Accident Classification System to analyze the maintenance-related mishaps. The system identified inadequate supervision, failed communications, skill-based errors, and procedural violators as the primary human error categories. The report shows how the Navy tool can be used to better categorize and understand maintenance-related mishaps attributable to human error.

1.2.8 Chapter 9: Technology Based Solutions for Process Management in Aviation Maintenance

Anand Gramopadhye of Clemson University and Jeff Millians of Galaxy Scientific Corporation wrote Chapter 9. This research project describes the software systems for Product Data Management (PDM) and their applicability in the aviation maintenance environment. The large deliverable of the project was an operational prototype of PDM to create maintenance workcards for a repair station application. That process and product is described, including the results of user acceptance tests.

1.2.9 Chapter 10: Maintenance Resource Management On-Line Seminar

Dr. Terrell Chandler of Galaxy Scientific Corporation writes Chapter 10. Like Chapter 4, this research report describes a substantive software product. This software is the most substantive deliverable of this task. The chapter describes the Safe Maintenance in Aviation Resource and Training (SMART). The entire software system can be viewed at FAA website (www.hfskyway.com). SMART was used to deliver a maintenance resource management course, worldwide, in early 1999. The chapter describes the operations of this distance education system and also describes the first application and system evaluation.

1.2.10 Chapter 11: Study of Fatigue Factors Affecting Human Performance in Aviation Maintenance

Ben Sian of Galaxy Scientific Corporation writes Chapter 11. The research project was a result of an NTSB recommendation to the FAA. The research report details an exploratory study that examines duty times for aviation maintenance technicians. The chapter offers a succinct explanation of fatigue, its causes, and its potential effects. Individual Report Summaries

1.3 INDIVIDUAL REPORTS

The research conducted in 1998-1999 also resulted in five stand-alone reports that are published on the website and in limited hardcopy. A brief summary of these reports is included here.

1.3.1 Development of Process to Improve Work Documentation of Repair Stations

The first individual research report was written by Professor Colin Drury and his colleagues at the State University of New York at Buffalo. This research report describes the results of interviews conducted with managers and maintenance personnel at six repair stations. The report is divided into four sections addressing 1) the environment, 2) quality systems, 3) labor turnover and training, and 4) multiple document formats. The report recommendations fall into the categories of documentation improvement, documentation standardization, error control mechanisms, turnover and training, and organizational pressure. The report's appendices are of value since they contain numerous examples of how to improve upon workcards.

1.3.2 Human Factors Good Practices in Fluorescent Penetrant Inspection

This individual research report was written by Professor Colin Drury of the State University of New

York at Buffalo. The report describes the important relationships among the organization, the procedures, the test equipment, and the human when conducting Fluroescent Penetrant Inspection (FPI). This report is very practical. It describes 86 best practices in nondestructive inspection techniques. The unique characteristic of this report is that it not only describes the best practices, but also offers tables of explanation as to why each best practice should be used.

1.3.3 Job Task Analysis of the Aviation Maintenance Technician

Ed Czepiel and Larin Adams at Northwestern University wrote the third individual research report. The substantive report will be available at FAA website (www.hfskyway.com). It is the end product of a five-year job task analysis. The study compares the results of a recent large industry survey to the findings of a similar study conducted as the Allen Study in the early seventies. The report is complete with numerous tables meant to have potential value to designers of aviation maintenance curricula.

1.3.4 Advisory Circular for Training Qualification and Certification of NDT Personnel

This Advisory Circular contains recommendations for the experience, training, qualifying, examining, and certifying nondestructive testing personnel for inspection of aircraft, engines, propellers, accessories, and components. The Advisory Circular recommends criteria for qualification of personnel requiring appropriate knowledge of technical principles underlying the nondestructive tests they perform.

CHAPTER 2
MAINTENANCE ERROR CAUSATION

David Marx
David Marx Consulting

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

2.1 EXECUTIVE SUMMARY

The specific issue addressed through this research is that of human error causation. That is, how do investigators search for the cause of an event, where do they stop their investigation in the causal chain, and how do they describe and document their causal observations? The research has been conducted because today, without formalized rules of causation, there is a wide variation in how investigators make causal determinations. This variation makes data analysis for common trends in the data difficult and makes for widely varying prevention strategies for factually similar events.

A 1998 FAA research report, *"Learning from our Mistakes: A Review of Maintenance Error Investigation and Analysis Systems,"* made two specific recommendation to the FAA regarding maintenance error causation:

> *All Flight Standards staff responsible for oversight of air carrier and repair station maintenance, including all principal maintenance inspectors and their staff, should be provided human error causal concepts training.*[1]

FARs 121.373 and 135.431 should be re-interpreted, given industry understanding of human factors, to require more thorough causal investigation of maintenance errors that impact the conformity of dispatched aircraft and/or endanger safety of flight.[2]

This research was conducted principally to support these two recommendations. Rather than have the FAA require a specific commercial tool (such as Boeing's Maintenance Error Decision Aid), this research provides the research foundation allowing air carrier and repair stations to evaluate the rigor of their own investigative processes. Additionally, it allows the FAA to evaluate the effectiveness of air carrier and repair station investigations within the FAA's oversight.

With the generous help of 231 members of the aviation community, this research was able to identify some of the investigative styles and biases that we all bring to the event investigation process. Through this learning, the following seven recommended rules of causation were developed in order to improve the event investigation process.

1. Causal statements must clearly show the "cause and effect" relationship.
2. Negative descriptors (such as poorly or inadequate) may not be used in causal statements.
3. Each human error must have a preceding cause.
4. Each procedural deviation must have a preceding cause.
5. Failure to act is only causal when there is a pre-existing duty to act.
6. Causal searches must look beyond that which is within the control of the investigator.

7. Statements of culpability must be accompanied by an explanation of the culpable behavior and its link to the undesirable outcome.

With these seven rules, air carriers, repair stations, and FAA inspectors can improve the reliability and effectiveness of their human error investigations. Implementing the rules is not easy – they require training to be used effectively, and, by design, require much more rigor in the actual investigative process. The benefit, however, is that investigations using these rules will more accurately identify and describe the conditions leading to human error.

2.2 INTRODUCTION

Every day, maintenance organizations face maintenance errors; earlier FAA research identified that roughly 48,000 aircraft flights are dispatched into revenue service each year with a maintenance error on board (physical discrepancy which is the result of a human error).3 Very few of these will result in an accident or major incident, with the vast majority having only an economic effect. If one were to additionally count those maintenance errors that are caught internally by the air carrier before the aircraft is dispatched into revenue service, the number easily runs into the hundreds of thousands of errors each year.

Consider that a large US carrier might generate 500,000 to 1 million maintenance log pages per year. Most of these maintenance logs include an investigation to determine "why" an event has occurred. If the event were an in-flight shutdown of an engine, a technician would investigate far enough to know how to put the aircraft back into revenue service without further complication. The technician will investigate to the extent that he/she is confident that after the repair, the engine will not again shutdown on the subsequent flight. In the case of a maintenance error, the investigation might conclude simply that a bolt was not properly lockwired. Once this is known, the technician will re-secure the bolt and the aircraft will again be put into service.

Under what circumstances, however, should the investigation go deeper into the contributing factors of either a human error or an equipment failure? Once the decision is made to dig deeper than the human error, how does one determine where the further investigation should go in terms of causal explanation? Surely there is little indecision about whether to dig deeper when the maintenance error has caused an accident or incident. Accident and major incident investigations have different goals than the simple event investigation by the technician – these events are investigated to learn how the event may be prevented in the future. Knowing that the bolt was not lockwired is not enough – here the failure of a technician to lockwire a bolt is viewed as the outcome and a search begins to determine why the bolt was not lockwired and how such an error may be prevented in the future.

Each carrier or repair station must decide when it will extend its investigation beyond the mere identification of the human error. Clearly, no carrier will conduct exhaustive investigations of each and every maintenance error occurring within their organization. Unfortunately, human error is complex in that it requires analysis of multiple events to fully understand how a particular process (e.g., shift turnover) might be contributing to human error events. It has become increasingly clear that most carriers today do not extend the investigation often enough to gain information on systemic contributing factors needed to optimize their error reduction efforts.

Once the decision has been made to go beyond mere identification of the human error event, the next and most difficult question is "Where should the investigation stop?" For many observers, the step beyond identification of the human error is a slippery slope; there is simply no clear guidance on when the causal search should stop. As a vivid illustration of this problem, consider the majority and dissenting opinions of the National Transportation Safety Board's recommendations regarding the Britt Airways (dba Continental Express) Embraer accident presented below:4

Statement of Probable Cause - Majority Opinion

> The National Transportation Safety Board determines that *the probable cause of this accident was the failure of Continental Express maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures for the airplane's horizontal stabilizer deice boots that led to the sudden in-flight loss of the partially secured left horizontal stabilizer leading edge and the immediate severe nose-down pitchover and breakup of the airplane.* Contributing to the cause of the accident was the failure of the Continental Express management to ensure compliance with the approved maintenance procedures, and the failure of FAA surveillance to detect and verify compliance with approved procedures [emphasis added].

Statement of Probable Cause - Dr. Jon Lauber's Dissenting Opinion

> The National Transportation Safety Board determines that *the probable causes of this accident were (1) the failure of Continental Express management to establish a corporate culture which encouraged and enforced adherence to approved maintenance and quality assurance procedures, and (2) the consequent string of failures by Continental Express maintenance and inspection personnel to follow approved procedures* for the replacement of the horizontal stabilizer deice boots. Contributing to the accident was the inadequate surveillance by the FAA of the Continental Express maintenance and quality assurance programs [emphasis added].

The difference between these two statements of probable cause is where the majority and Dr. Lauber place their principal cause for the accident. The majority identified as cause the technicians on the floor who did not follow company procedures as the cause; Dr. Lauber, a prominent human factors expert, pointed the causal finger directly at management and the corporate culture they had created within Continental Express. This was a step that the majority of the NTSB members were unwilling to take. The same dilemma follows FAA field inspectors and internal air carrier mishap investigators. That is, what explanation of an event will best serve aviation safety? Is Dr. Lauber's probable cause more accurate than that of the majority? Can an internal corporate investigator reasonably (or politically?) point the finger at corporate culture as the cause of a mishap? Should the search for cause be different if one is investigating a mere delay or cancellation as opposed to an aircraft accident?

At a recent human factors workshop with approximately 40 attendees, I asked small groups to assess the validity of the two causal explanations offered by the NTSB members, and to identify which route they would take if conducting the investigation in their own organization (assuming there had not been an accident). All participants thought that Dr. Lauber's dissenting opinion more accurately addressed the "true" causal aspects of the accident. Nevertheless, not all agreed that they would follow Dr. Lauber's path inside their own carriers. Many felt that Dr. Lauber's opinion put more emphasis on blame, especially where he pointed out the blameworthy disposition of certain Britt Airways managers in the full text of the NTSB report. Additionally, there were some participants who believed that the majority opinion said enough about process deficiencies and need not point to "culture" and "management" as the probable cause. Many participants felt that the implication in the majority opinion was clear that management would have a role in solving the procedural non-compliance on the floor.

The issues raised by the differing opinions of the NTSB are those that this research explored. As investigators, some of us may look to the duties of each individual and breaches of those duties; others may look for rule violations and possibly the human factors behind those rule violations; still others may immediately extrapolate to the system-level problems, such as the CEO's creation of an environment of high pressure. It is not that any of these explanations is incorrect, but rather that system safety may be better served by some causal explanations than others. Today, in the context of broad-scale maintenance error investigation, the lack of standardized rules of causation results in unacceptably varied investigative conclusions from one individual to another. For example, as discussed later in this report, survey respondents were asked to determine the root cause of an event involving an aircraft being towed into a jetway. While some respondents cited the individual error of the tug driver as the root cause, many other respondents cited a much more attenuated marketing error as the root cause of this same event (see first scenario in Appendix B). By understanding how investigators determine the cause of the event under investigation, this research brings more structure to our human factors investigative processes and provides much more predictability and repeatability in investigative outcome.

This research included three major tasks: first, to develop a preliminary taxonomy describing the models of causation available to an event investigator (e.g., probable cause, root cause, but-for causation, proximate cause) as well as the possible environmental factors impacting an investigator's determination of cause (e.g., investigator's experience, investigator's relationship to the erring employee); second, to conduct a scenario-based survey to determine scientifically how different investigative approaches and investigative language shape the determination of cause among a diverse group of Engineering and Maintenance professionals. Through these two tasks, the third step of the research was to develop a proposed set of rules of causation that can be used by both air carriers and regulators in their investigation of mishaps, or oversight of air carrier mishap investigations, respectively. The rules, however, are not a panacea – they do not replace investigative experience and they do not, nor could they, eliminate all investigative biases. Nevertheless, by developing rules of causation, investigators, managers, and regulators can be assured that causal explanations of human error events will be more analytical, more consistent, and in the end, be in the best interests of safety.

To understand the survey data and how the rules of causation were developed, it is advisable to read Appendix A. This appendix sequentially illustrates how an event investigation can proceed from what can be known about an event to a small set of written statements in the final investigative record. With this albeit stereotypical investigation in mind, the survey data and the rules of causation become more clear.

2.3 THE SURVEYS

This research queried whether the selected causal influences listed in Appendix A can be seen in the industry's current maintenance error investigative process. Additionally, the research attempted to uncover any specific investigative biases that may have emerged as air carriers increase their investigation of maintenance errors. For example, would individuals trained as investigators view as dominant certain causes that would not be seen as causal by other non-investigators? The following specific hypotheses were tested through the use of surveys:

- *There will be wide variation in where participants will stop their causal search as they investigate back the causal chain.*
- *Positive and negative descriptors will influence the strength of causal explanations, even when the underlying factual context is unchanged.*
- *The presence of a rule or procedural violation will increase the causal strength of the violation's underlying facts.*
- *The presence of a possible prevention strategy will decrease the perceived contribution of other causal factors, even when the underlying factors leading to subject mishap have not changed.*
- *Rule violations and possible prevention strategies will lessen the relative strength of probabilistic causes such as fatigue or stress.*
- *Different investigative styles will appear, depending upon the job function, education, and investigative training of the individuals involved.*

To test these hypotheses, two versions of three different scenarios were created. Participants received one version of each scenario. Each scenario had two elements: a narrative explanation of the mishap, and a list of open questions that queried what the participant believed to be the causes of the subject mishap. Designed to work as pairs, the scenarios allowed testing of the validity of the six hypotheses discussed above. Each participant was asked to identify the dominant contributor, the second most dominant contributor, the third most dominant contributor, and the "root cause." A summary of the six scenarios is provided in the tables below. The actual scenarios are provided in Appendix B.

First Pair of Surveys

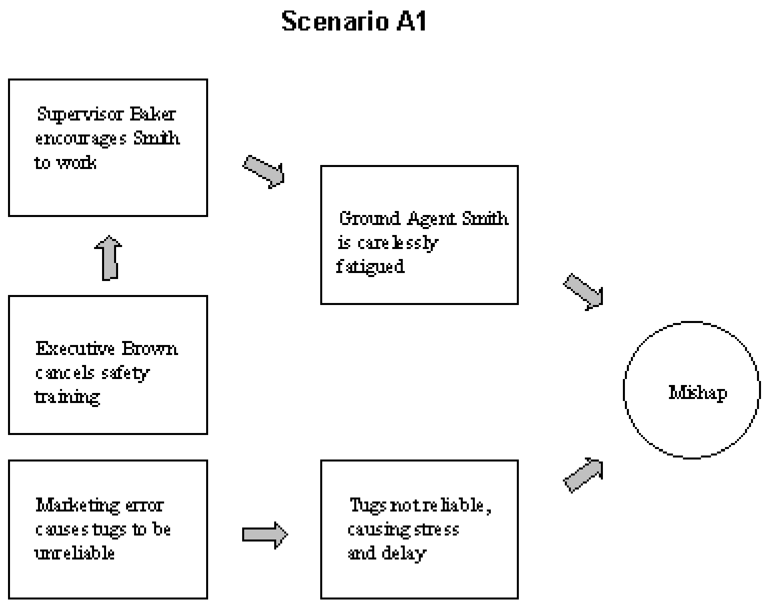

Figure 2.1 Scenario A1

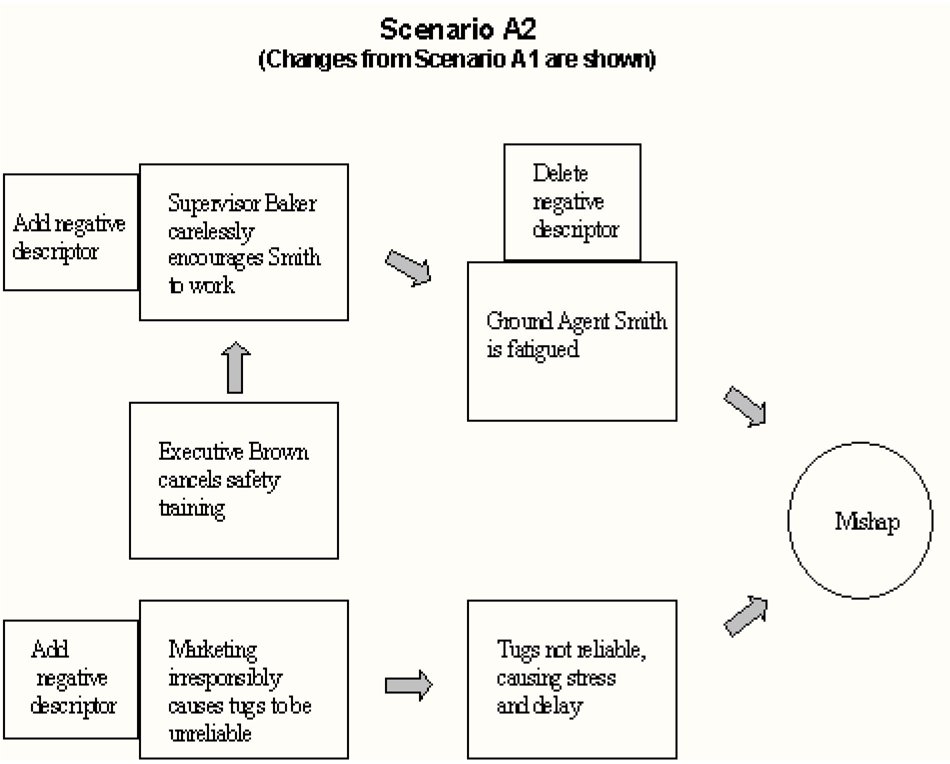

Figure 2.2 Scenario A2 (Changes from Scenario A1 are shown.)

Second Pair of Surveys

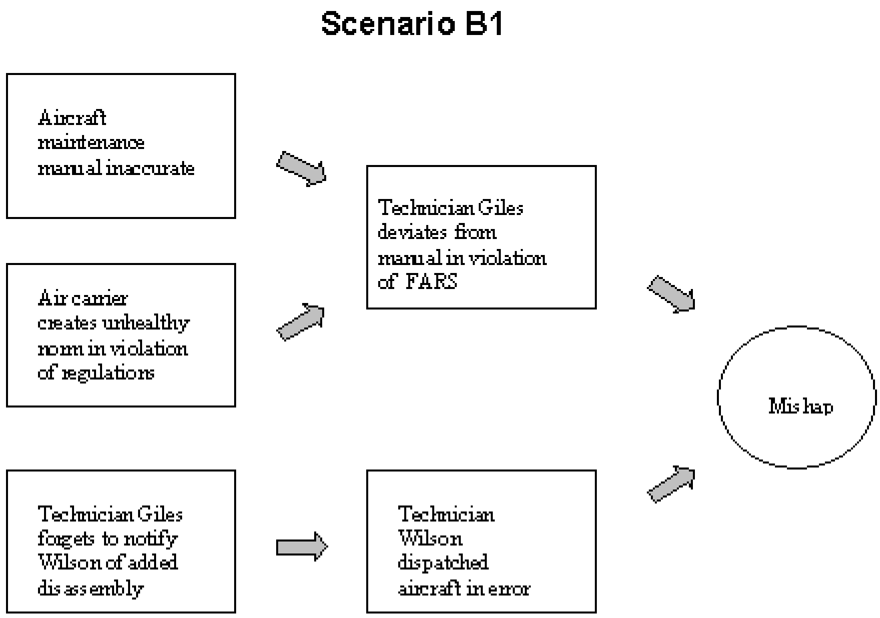

Figure 2.3 Scenario B1

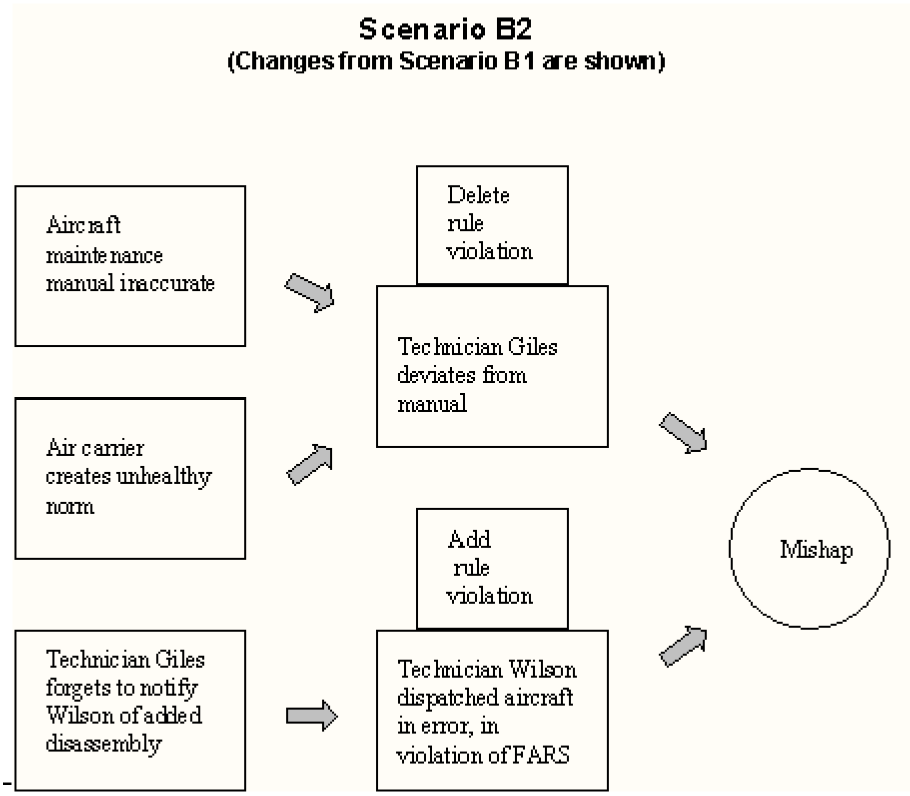

Figure 2.4 Scenario B2 (Changes from Scenario B1 are shown.)

Third Pair of Surveys

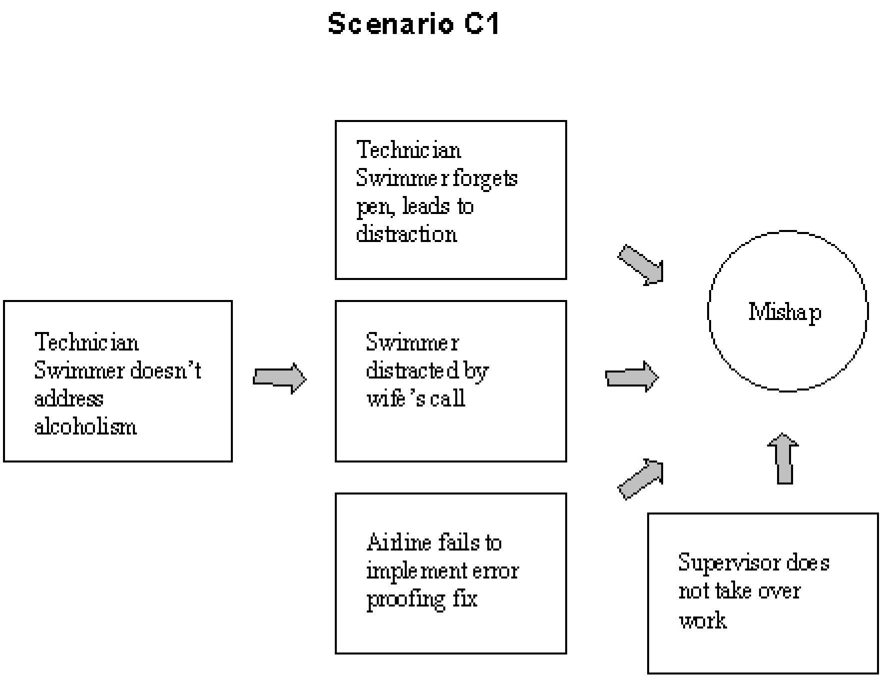

Figure 2.5 Scenario C1

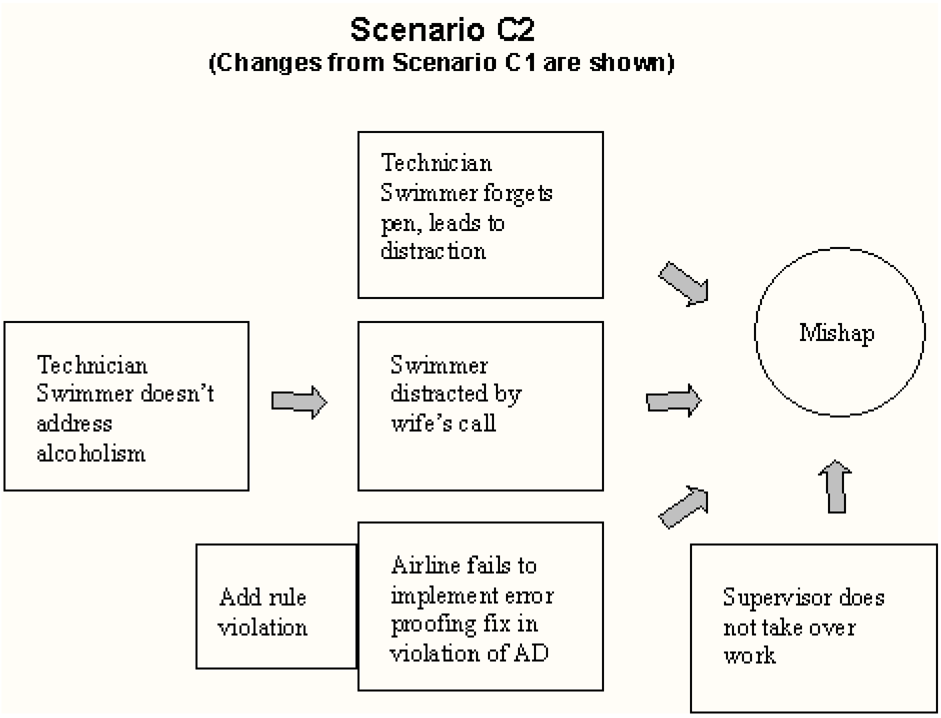

Figure 2.6 Scenario C2 (Changes from Scenario C1 are shown.)

2.4 DATA ANALYSIS

In all, 231 individuals representing 35 different organizations around the world provided over 2700 individual data points on causal biases in the event investigation process. This data has been organized and sorted by region of the world, investigator training, Crew Resource Management training (in maintenance known as maintenance resource management – MRM), years of experience, and by respondent's role within their organization.

Each of the six principal hypotheses discussed earlier is listed below with an analysis of how each was supported by the data.

Hypothesis 1 - There will be wide variation in where participants will stop their causal search as they investigate back the causal chain.

As seen in Figure 2.7, there was extremely wide variation in what each respondent identified as their first, second, and third contributors, as well as root cause. For example, in the first version of scenario A, eleven different dominant causes were identified. That is, the 100 respondents found 11 different dominant causes, ranging from the error of an employee who towed the aircraft into a jetway to the financial troubles of the air carrier. This data vividly confirms that what is dominant in one investigator's mind may not necessarily be the dominant contributor in another's.

To understand these findings, this research must be distinguished from actual mishap investigation. In the actual mishap investigative process, the investigator will stop the investigation for a number of reasons - from natural stop rules to organizationally imposed stop rules. In contrast, in this research the respondent is already provided with investigative conclusions that go back farther in the causal chain than the participant might go in his own organization. In this research, the participant only needed to prioritize which factors he believed were most dominant in the mishap.

In virtually all responses, survey participants were willing to identify three top contributors and a root cause. In the first scenario, over 80% of the respondents identified their root cause at the airline level (i.e., financial troubles, poor decisions made by corporate executives). Importantly, when given a variety of different causes there was very little difference in how far back the causal chain participants were willing to go regardless of whether or not they were trained mishap investigators (research participants were principally Boeing Maintenance Error Decision Aid (MEDA) trained investigators). Respondents, both investigative trained and not, were willing to embrace a long causal chain. At a high level, there was a consistent trend in the data. As seen in Figure 2.8, most individuals in survey scenario A1 put the dominant cause at the level of the erring employee while most put root cause as far back the causal chain as was possible (i.e., at the airline management level). While this effect was seen throughout all three scenarios, as the perceived culpability of the employee increased, the erring employee increasingly became both the dominant and root cause, as shown in the data from scenario C (see Figure 2.9).

It is important to recognize that when investigating events within an actual air carrier or repair station investigation, investigators are rarely, if ever, willing to go up the organizational chain as they did under these scenario circumstances. This raises the important question of what causes investigators in the real world to stop the investigative search and why?

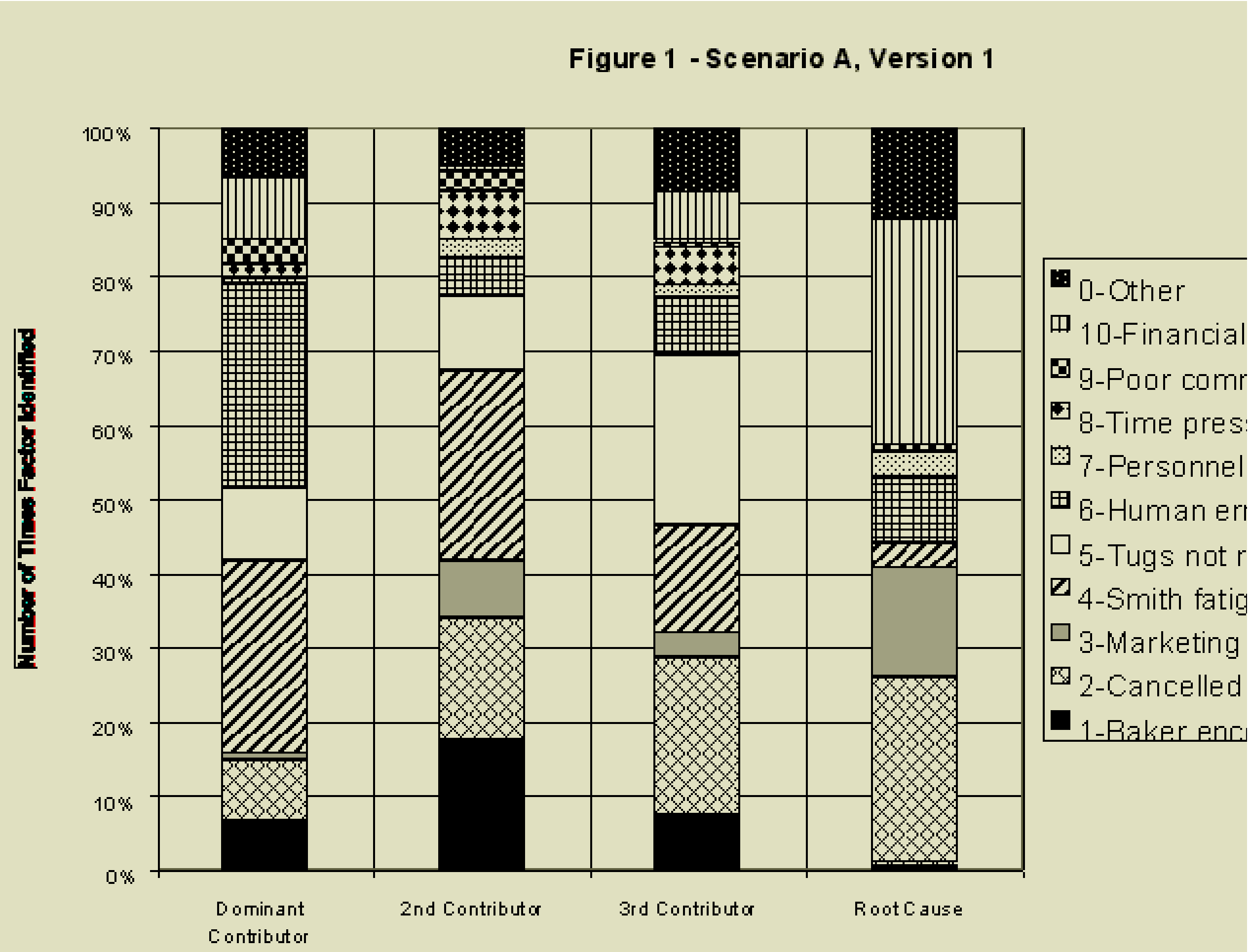

Figure 2.7 Scenario A, Version 1

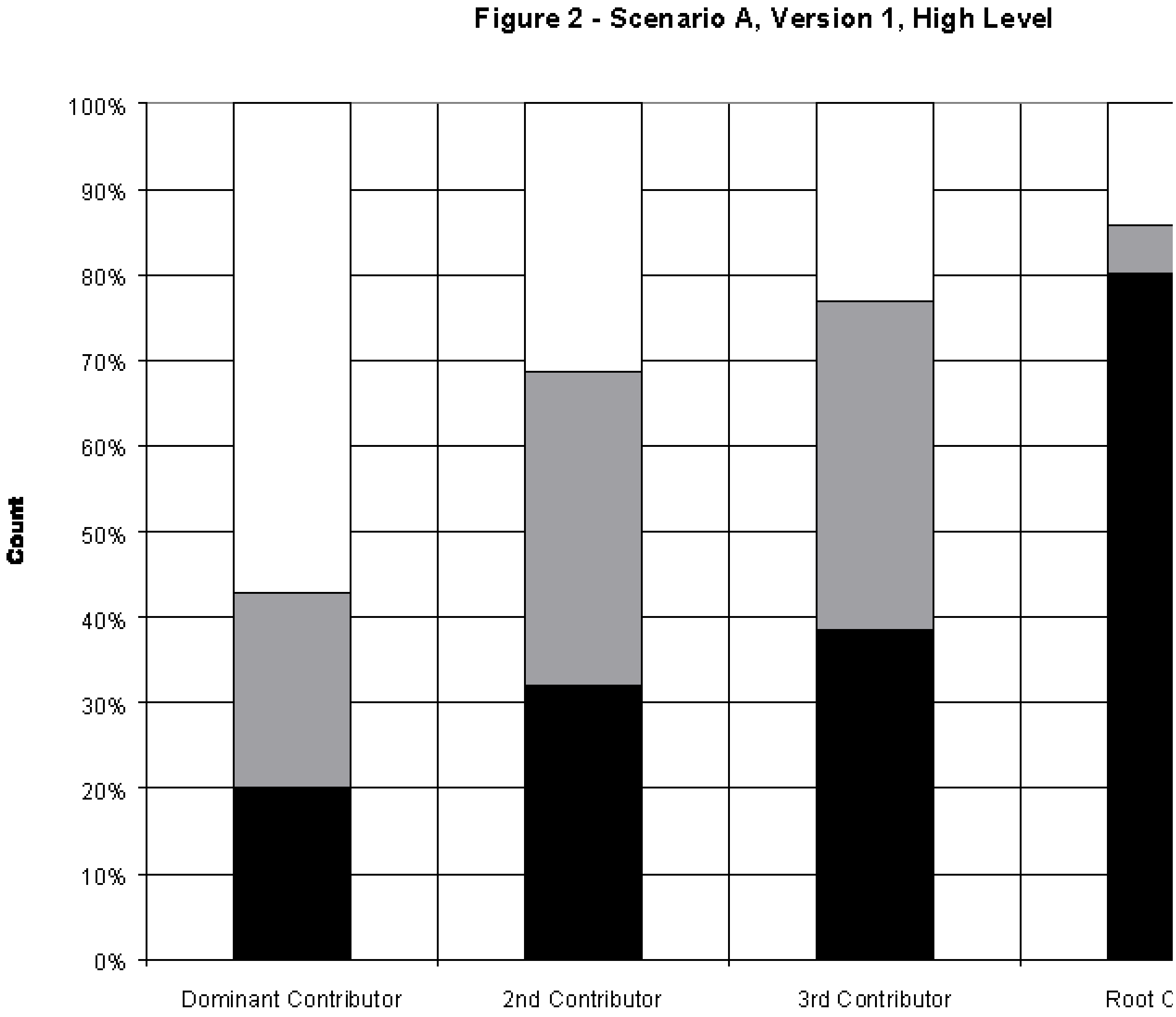

Figure 2.8 Scenario A, Version 1, High-Level

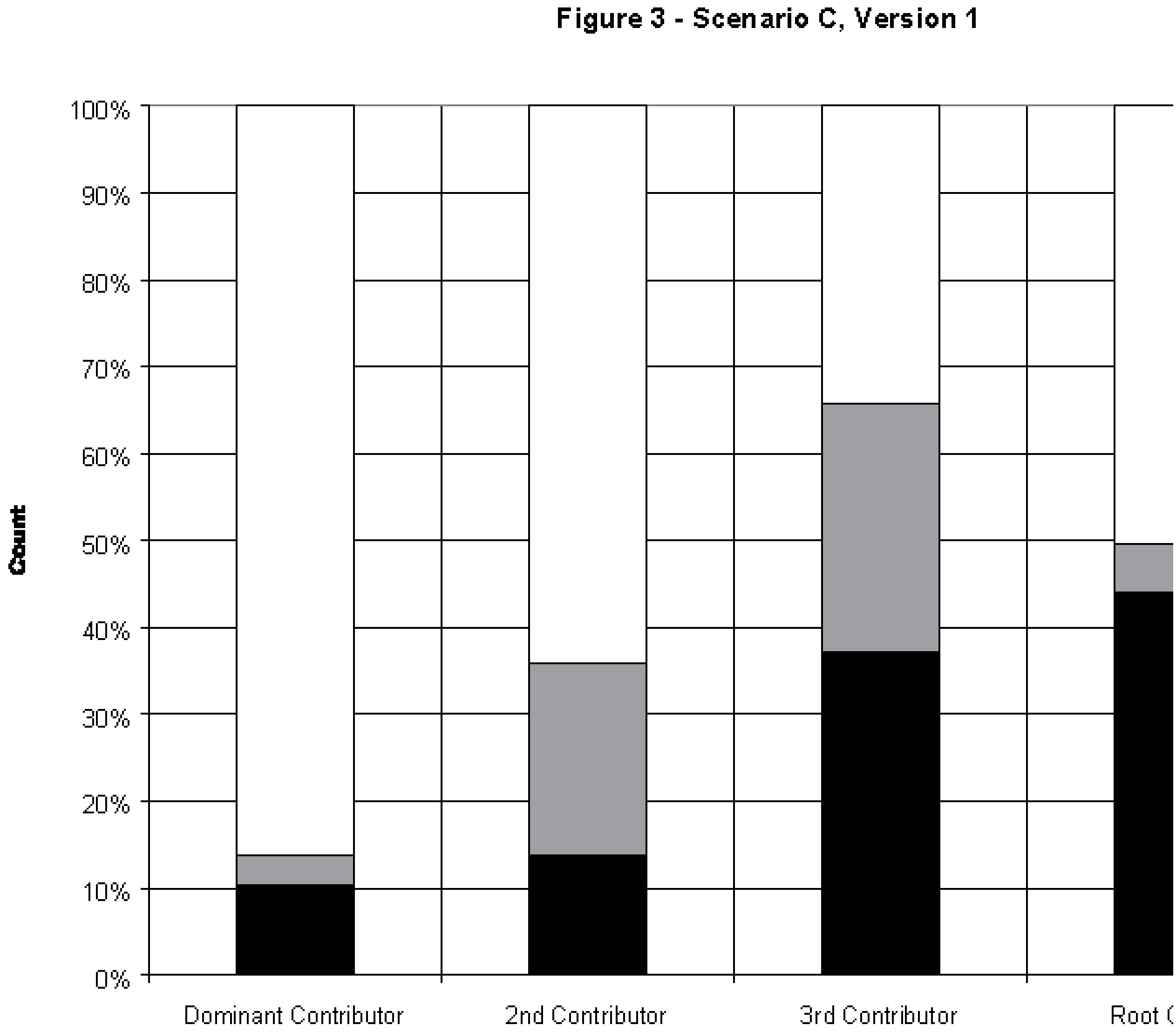

Figure 2.9 Scenario C, Version 1

> *Hypothesis 2 - Positive and negative descriptors will influence the strength of causal explanations, even when the underlying factual context is unchanged.*

An unexpected but encouraging finding was that the data showed little variation when negative wording was attached to particular causes. The factual strength of the underlying causal assertions seemed to control the relative rankings of contributors by the respondents, regardless of the addition of negative descriptors.

However, the relevance of the negative descriptors was found in the quality of the narrative itself. Many narratives used negative descriptors as a "short-hand" to describe the inadequacies (causes) respondents saw in the mishap narrative. For example, one respondent wrote, "maintenance manual was poorly written." These types of causal statements lack the specificity required to fully understand the cause and effect relationship in the detail that would allow a productive prevention strategy to be built. For example, what would be the fix for "maintenance manual was poorly written?" Without a statement of a specific cause and effect relationship, causal statements merely become value judgements about the object under investigation. The table below shows many of the shorthand descriptors used by respondents.

Table 2.1 Use of Descriptive Words

Words Used by Respondents	Scenario A	Scenario B	Scenario C	TOTAL
"Lack of"	143	97	93	333
"Failure to"	22	62	57	141
"Poor"	58	48	27	133
"Insufficient"	13	1	2	16
"Inadequate"	18	27	13	58
"Should or should have"	27	33	61	121
"Bad"	9	4	6	19
TOTAL	**290**	**272**	**259**	**821**

It is significant to note that when the employee was viewed as more culpable (in scenario C), respondents more often chose to use the words "should" and "should have." This would suggest that as the erring employee is viewed as more culpable or there are less obvious contributing factors, the investigator tends to turn away from human error contributors to statements of what the erring employee should have done to prevent the mishap. That is, instead of saying what caused the employee to so what he did (i.e., the error), the respondents showed more propensity for merely stating what the employee could have done differently.

Hypothesis 3 - The presence of a rule or procedural violation will increase the causal strength of the violation's underlying facts.

The presence of a rule violation did, as suspected, affect the strength of the causal statements. When the rule violation involved some amount of intent on the part of the technician, respondents were much more willing to highly rank the violation as causal in the mishap. This occurred even when the underlying behavior was unchanged – except for the behavior being identified as an FAR violation. The specific language where a procedural violation in one version was identified as a violation of the Federal Aviation Regulations.

Scenario B, Version 1

Although the proper course was to prepare a non-routine work order documenting the added removal, line maintenance technicians were encouraged to deviate from the manual instructions to get the job done. *Although the deviation is a violation of Federal Aviation Regulations, management felt there would be no harm* [emphasis added].

Scenario B, Version 2

Although the proper course was to prepare a non-routine work order documenting the added removal, line maintenance technicians were encouraged to deviate from the manual instructions to get the job done. *As long as the added work was remembered, management felt there would be no harm in the deviation* [emphasis added].

With the mere addition of the FAR violation, respondents were much more willing to identify the deviation in version 1 as higher in causal strength than that in version 2. Unlike violation requiring some level of intent, what did not change the respondents' causal determinations was an outcome-based rule stating that to make the human error was a violation of the FARs. For example, FAR

43.13 states that no aircraft can be dispatched out of conformity with its type design. In this case where there was no intent to violate the rule implied in the scenario, there was no change in the causal strength between scenarios identifying the rule violation and those that did not.

> *Hypothesis 4 - The presence of a possible prevention strategy will decrease the perceived contribution of other causal factors, even when the underlying factors leading to subject mishap have not changed.*

The presence of a possible prevention strategy did lower the ranking of other contributing factors in a scenario. Here, a possible prevention strategy was defined as a strategy, unrelated to the principal human error, that would have nonetheless prevented the mishap. In scenario C, it was a supervisor who might have prevented the mishap by checking the work of the employee. Although there were specific contributors to the principle human error, the possible prevention did rank higher in causal strength than many causes specific to the human error.

> *Hypothesis 5 - Rule violations and possible prevention strategies will lessen the relative strength given to probabilistic causes such as fatigue or stress.*

Both rule violations and the presence of possible prevention strategies did act to lessen the strength of probabilistic causes. The relevance of this finding is important if one believes that better prevention strategies will come from measures to reduce the effect of the more “human factors-oriented” probabilistic causes such as fatigue or confusing procedures. By diverting the causal search toward rule violations and possible prevention strategies, investigators may overlook more manageable causes. Boeing’s MEDA tool specifically ignores rule violations because of this possible bias.

> *Hypothesis 6 – Different investigative styles will appear, depending upon the job function, education, and investigative training of the individuals involved.*

There were no clear differences in investigative styles when analyzed according to years of experience, job function, CRM/MRM trained, or error investigation trained. The only finding of statistical validity among these factors is that CRM/MRM trained respondents were more willing to identify the presence of a norm as the dominant contributor to a mishap. This likely results from the focus that many maintenance CRM/MRM programs give to the issue of norms.

2.5 SUGGESTED RULES OF CAUSATION

Based in part on the data collected above, the following rules of causation were developed to help control the direction of the causal search in a mishap investigation, as well as control the language used to describe causal statements. The rules are an initial set of rules on the way to improving the investigative process by improving the repeatability, predictability, and clarity of investigations. Employing these rules is simple: where you attempt to explain “why” an event has occurred, apply these rules to the explanation. If the explanation of “why” the event has occurred conforms to the seven rules, you have met the minimum standards for causal explanation.

1. Causal statements must clearly show the “cause and effect” relationship.

While this is the most basic of causation rules, it cannot go unstated. For a variety of reasons, the investigator who understands the cause and effect relationships in an investigation may nonetheless document only a few of the causal links. If there are multiple links in the causal chain of an event, there should be a causal statement for each link. For example, in the first research scenario, many respondents identified the air carrier’s financial problems as the root cause of an aircraft towed into a jetway. While this is acceptable within these rules of causation, the investigator must show the link (s) between the financial troubles and how a technician was able to tow an aircraft into a jetway. Properly identifying all of the causal links is particularly important because an organization may find that breaking the chain of events at an intermediate link is the most effective course of action.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
The cancellation of fatigue training increased the likelihood that Supervisor Baker would not detect the fatigue of her employee.	Because of a marketing error which hurt the financial stability of the carrier, a technician towed an aircraft into jetway. *(Does not show intermediate cause and effect links)*

2. Negative descriptors (such as poorly or inadequate) may not be used in causal statements.

Contrary to expectations, this research did not show that negative descriptors significantly altered the strength of causal determinations. However, the raw data did show that negative descriptors act as a shorthand that can inadvertently mask a more specific cause and effect relationship. The statement "maintenance manual was poorly written" masks the real cause and effect relationship. That is, it fails to specify exactly what was mis-written, which in turn contributed to the error.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician installed oil cap improperly because the maintenance manual mistakenly showed the cap with a 1/8" gap at the cap to flange interface, thus increasing the likelihood of the error.	In-flight shutdown caused by loose oil cap. Maintenance manual procedure was poorly written causing oil cap to be improperly installed. *(No additional information provided beyond the statement of the procedure's inadequacy)*

3. Each human error must have a preceding cause.

Boeing's Maintenance Error Decision Aid (MEDA) tool was designed in large part to take the investigative search beyond the mere identification of the human error, the place where most mishap investigations have tended to stop. This causation rule merely makes explicit what is implicit in MEDA: that the investigation must search beyond the error to why the error has occurred.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by mis-installed oil cap. Technician was distracted by outside noise, increasing likelihood of error. Technician was fatigued after working 12 hours increasing likelihood of the error.	In-flight shutdown caused by mis-installed oil cap. *(No additional information provided beyond the identification of the error.)*

4. Each procedural deviation must have a preceding cause.

The data from this research showed that the presence of a rule violation impacts the causal strength of the underlying facts. In some cases, respondents wrote that “failure to follow maintenance manual procedures” was a cause of the event. To be beneficial, a causal statement involving a rule or procedural deviation must show a link to the undesirable outcome. Additionally, in order to develop a good prevention strategy, the rule violation itself must be explained through a cause of its own. For example, in the example below, the investigator must search for why the maintenance manual procedures were not followed.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician did not have work card with him at time of error, increasing the likelihood of the error. Technician did not have procedure with him because a norm had developed that tasks would be signed off after completion of all.	In-flight shutdown caused by loose oil cap. Technician failed to follow general maintenance manual requirements. *(No additional information provided beyond the identification of the procedural violation.)*

5. Failure to act is only causal when there was a pre-existing duty to act.

The data in this research showed wide variation in the respondents’ willingness to identify failure to implement a particular prevention strategy as a “cause” of the mishap. This rule attempts, at a high level, to distinguish possible prevention strategies from the specific “causes” of a particular event. The classic illustration of this rule is the truck with a brake failure that cannot stop and hits a person in the crosswalk. The brake failure will undoubtedly be seen as the principal contributor to the event. Now consider a bystander on the sidewalk who, if he had run into the street, could have pulled the person from the crosswalk, thus preventing the mishap. The bystander is clearly able to prevent this incident; however, most observers would not identify the bystander as causal in the mishap. Now consider the additional knowledge that the bystander is a school crossing guard and that the person in the crosswalk is a 6 year-old child. In this case, the school crossing guard has a duty to act – to prevent the mishap. In this case, in addition to the brake failure, most individuals will consider the crossing guard to be a contributor to the mishap.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician distracted by outside noise, increasing likelihood of error. In-flight shutdown also caused by failure to complete the engine run-up in the maintenance manual procedure. An engine run-up was not performed because the technician thought that it was already completed by another technician.	In-flight shutdown caused by loose oil cap. The in-flight shutdown might have been prevented had the technician at the next gate checked the erring employee’s work. *(No requirement or duty for the technician to act).*

6. Causal searches must look beyond that which is within the control of the investigator.

Although not tested in this research, many investigators do stop the investigation at factors only within their control. That is, if the investigator is not in a position to change the contributing factor, then the investigator will not identify the factor as causal, in the belief that there is no reason to identify as causal what you cannot change. The problem with this belief is that what might not be changeable from a single investigation might in fact be changeable if it is present in an entire class of events. That an investigator feels he will not be able to change an awkward design does not mean that the company will not be able to change the design of the aircraft if it has led to numerous events. This rule makes explicit that investigative conclusions should not be controlled by the investigator's perceived extent of control.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician was fatigued after working 18 hours in the cold, increasing likelihood of the error. Aircraft design made it difficult to turn the cap while wearing gloves, increasing the likelihood of the error.	In-flight shutdown caused by loose oil cap. Technician was fatigued after working 12 hours in the cold, increasing likelihood of the error. *(No additional information provided about the design because the investigator felt it would be too hard to change.)*

7. Statements of culpability must be accompanied by an explanation of the culpable behavior and its link to the undesirable outcome.

Many of the respondents in this research used "carelessness" and other words of culpability as contributors to events. In most cases, however, the culpability "label" was not accompanied by a statement of what behavior was blameworthy nor how the culpable behavior was related to the undesirable outcome. Especially important when assessing personal blame, this rule requires the investigator to identify the culpable behavior and its relationship to the outcome.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician was fatigued, increasing the likelihood of making the error. Technician was reckless in that he took a substantial and unjustifiable risk in working 18 hours straight prior to making the error.	In-flight shutdown caused by loose oil cap. Technician carelessly worked in an unsafe manner. *(No additional information about basis of culpability or relationship to the error.)*

2.6 CONCLUSION

This research showed that there is still wide variation in what individuals will identify as dominant and root causes to maintenance errors. If we are to collect consistent maintenance error data, we must have more standardized rules to provide minimum guidelines on what is an acceptable explanation as to why an human error event has occurred.

The seven rules of causation contained in this report fill this need by adding more rigor to the investigative process. The rules can be used with a specific investigative tool such as MEDA or in pure narrative reports such as an air carrier's voluntary disclosure to the FAA. Additionally, they can be used by FAA field inspectors to help assess whether an air carrier or repair station is conducting effective, safety-supportive investigations. If followed, these rules force the maintenance organization to specific causal descriptions that will serve maintenance error analysis and, consequently, system safety improvement.

2.7 ACKNOWLEDGEMENTS

Special thanks go to William Rankin, Ph.D., at Boeing, for his support in the design of the surveys, Krisiti Schiller for her data entry and analysis and my wife, Dawne Marx, for her tireless editing and support.

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2.9 APPENDIX A THE EVENT AND CAUSATION TAXONOMIES

The Event Taxonomy

In developing a taxonomy of factors that may influence the causal explanation of an event, it was first necessary to document what, in theory, can even be known about an event. In general terms, what can be known about an event is shown in the table below. Depending on what an event investigator deems important, some or all of these elements may be identified in an investigative record.

At a high level, information pertaining to the mishap can be grouped into three basic questions: what was (the error), what usually is (the norm), what was supposed to be (the rule). For example, relative to lighting in a specific area of inspection, the three questions are as follows:

- What was in this mishap: No supplemental lighting at all

- What usually is: A standing electric light
- What was supposed to be (per the manual): A portable flashlight

Specifically, what can be known about an event is as follows:

Item	Description	Example
Particulars	Defines mishap in space and time.	The mishap occurred in Atlanta at 6:00 p.m.
Behaviors	Actions of the people involved.	Bob pressed the switch to open the cargo door.
Intent	Knowledge with respect to individual behaviors.	Bob did not intend to hit the cargo door switch.
Outcomes	Results of behaviors or events.	The aircraft experienced an in-flight depressurization.
Performance Shaping Factors	Conditions present that influenced the performance of system elements (human or equipment).	The technician was fatigued.
Rules, Procedures, and Duties	Prescriptions imposed upon one's behaviors.	Technicians must follow the maintenance manual procedures.
Norms	What is normally done.	Generally, only one wing walker is used.
History	Background information to support a specific fact.	The maintenance manual procedure was modified three years ago.
Prevention Strategies	Actions that could have been taken to prevent the mishap.	A functional test would have caught the discrepancy.
Cause and Effect Relationships	*Relationship between a cause and its resulting effect.*	*A fatigue crack caused the stringer to fail.*

The following scenario shows how these elements might be seen in the narrative story of a mishap.

> Mr. Giles and Ms. Wilson are maintenance technicians at the Phoenix airport. *(particulars)* Mr. Giles works first shift and Ms. Wilson works second shift. *(particulars)* Near the end of first shift on May 2, 1994, Mr. Giles was required to troubleshoot an MD-80 that experienced a pressurization fault on its flight into Phoenix. *(particulars, duty)* Mr. Giles isolated the fault to a bleed air valve on the left engine. *(behavior)* Following the maintenance manual, Mr. Giles began to remove the bleed air valve. *(behavior)* Mr. Giles found the valve difficult to remove, so he loosened two additional bleed air duct clamps to add flexibility to the assembly. *(behavior)* Although required by company policy, Mr. Giles did not write on the

maintenance log that he had loosened the two additional clamps. *(behavior, rule)* It is the norm in the airline that if you are going to personally complete the work, then no specific write-up is needed for the added disassembly. *(norm, intent)*

Immediately after removing the valve, Mr. Giles took the valve to the storeroom across the airport to look for the spare. *(behavior)* No spare was found, so he was required to borrow the valve from another carrier at the airport. *(performance shaping factor, behavior)* By the time Mr. Giles returned to the aircraft, his replacement, Ms. Wilson was coming on duty. *(performance shaping factor, behavior)* Mr. Giles verbally briefed Ms. Wilson on the condition of the aircraft and her need to install the valve, but forgot to inform her of the two additional clamps he had loosened. *(performance shaping factor, behavior)* Ms. Wilson installed the valve correctly, but never looked to see if the additional two clamps had been loosened. *(behavior)* The airplane departed Phoenix unable to pressurize. *(outcome)* The airplane had to return to Phoenix to have the clamps tightened. *(outcome)*

Upon further investigation, it was discovered that Mr. Giles and Ms. Wilson have known each other for quite some time. *(history)* Ms. Wilson had once dated Mr. Giles's brother and now they were no longer friends. *(history)* Through the testimony of a few of Mr. Giles's colleagues, it was determined that Mr. Giles had repeatedly left Ms. Wilson with incomplete write-ups. *(history, behavior)* In the past, one colleague had overheard Mr. Giles say that it would be up to Ms. Wilson to figure out what to do. *(intent)*

Additionally, the investigation found that Ms. Wilson forgot to perform a leak check of the system as required by the carrier's general maintenance manual. *(rule)* Had Ms. Wilson performed the check, the leak from the two loosened clamps would have been detected. *(possible prevention strategy)*

While the labels attached to each sentence are subject to some interpretation, the important point is that the above elements known about this mishap investigation can be categorized according to the previous taxonomy. The job of the mishap investigator is to determine where the investigation should go and what should be included in the mishap record. That is, what questions should be asked of Mr. Giles and Ms. Wilson? What are mere conditions or facts unrelated to the undesirable outcome, and what in the mishap is causal? Additionally, how should the investigative record be written to avoid likely biases or mis-interpretations by future readers of the mishap record?

While some investigative records may contain a narrative similar to the example described above (typical in self report programs such as NASA's Aviation Safety Reporting System (ASRS) where a respondent tells a narrative story and the reader is left to determine the causal relationships), many investigation records will not include a narrative like the one above. The maintenance technician investigating only to fix the problem and get the aircraft dispatched will not care about most of the information in the narrative above. The MEDA investigator will not include the narrative because MEDA is a causal statement driven tool that lists investigative conclusions in lieu of a narrative description. Lastly, one must consider how investigations are discussed within the corporate context. When the Vice President of Line Maintenance wants to know "why" a forklift was driven into the side of his aircraft he is not asking for the narrative. Rather, he is asking for cause and effect statements – something missing from the narrative description of the mishap above.

The following Taxonomy shows how an investigative process can condense a narrative into investigative cause-and-effect conclusions.

The Causation Taxonomy

In an event investigation, determining the cause and effect relationships are where the most interpretation, and bias, will occur. The following table lists the specific factors that will influence the cause and effect determinations made by event investigators. For an excellent treatise on investigative (attribution) theory, see Fiske And Taylor's book, Social Cognition, to which this taxonomy owes a great deal of credit.5

Issue/Bias	Description
Investigative Purpose	Why the investigation is conducted: to merely explain an event, to predict future events, to prevent future events, or to allocate responsibility or blame.
Investigator Model	What is expected of investigator: to search for causation without bounds (the scientific method) or to apply generalizations, assumptions and stop rules to arrive at a "proximate" cause.
Human Error Models	James Reason's Swiss Cheese (multiple links in chain from senior management to erring employee)6 Contributing Factors (such as in MEDA – largely oriented toward local factors) Human Reliability (oriented toward task reliability – implied that entire organization shapes reliability)
Levels of Causation	In-Fact (if A, then B) Probabilistic (If A, increased likelihood of B) Proximate (limits causal search) Root (extends causal search)
Temporal Contiguity	Factors closer in time to undesirable outcome will more likely be labeled as causal.
Spatial Contiguity	Factors or objects closer in space/location to the undesirable outcome will more likely be labeled as causal.
Perceptually Salient Stimuli	Perceptually salient stimuli (factor first drawing the attention of the observer) will more likely be labeled as causal.
Severity Effects	Big effects must have big causes.
Representative Causes	Inferring that the cause of similar historical events will be the cause of the event at hand.
Hedonic Relevance	Impact of error on investigator's interests. Greater the negative impact on the investigator's interests, the more likely the cause will involve culpable behavior.
Counterfactual Variations	Developing a description first of what should have been. Then, comparing actual events to the counterfactual to determine what is causal.
Mental Models	Investigative data being loaded into the investigator's pre-existing mental model of either the error or the erring employee. For example, if erring employee is thought of as conscientious, then investigator may be less inclined to find culpable behavior.
Personalism	Inference that erring employee's conduct was

	intended to harm investigator.
Covariation	Observed coincidence of two events, generally over multiple occurrences - coincidence infers causation.
Discounting and Augmenting	Relevance of one causal explanation being enhanced or discounted based upon presence of another causal explanation.
Self Perception	Inferring internal states from external or environmental factors. For example, inferring fatigue based upon remembering work schedule, rather than actually feeling fatigued.
Natural Stop Rules	Natural limits to investigative depth and breadth presumably developed through life experience.
Fundamental Attribution Error	Attributing another's behavior (error) to his disposition (e.g., he's a careless or lazy worker).
False Consensus	Tendency of erring employee to view his own behavior as typical of what others would do under the circumstances.
Self-Serving Bias	Taking credit for one's success, blaming others for one's failures.
Self-Centered Bias	Tendency to take a greater share of responsibility than is actual.
Locus of Control (two meanings)	A style issue: Externals believe that events are caused by external factors; Internals believe that events are under their own control. In the mishap investigative context, many investigators will identify as causal only conditions that are within their ability to change.
Investigative (Attributional) Styles	Tendency to make similar causal inferences across different event scenarios - can be based upon job function, education, and training as examples.
Linguistic Biases	Use of descriptors and sentence structure to augment the strength of a causal statement.
Rule Violation Bias	Identification of rule violation may impact causal determinations.

Each of these factors can be present within the investigative process. For example, consider the following hypothetical view of the Giles and Wilson event investigation discussed earlier. What follows are the specifics of how an event investigator, Fred, might go about his investigation.

> Fred is assigned to investigate Mr. Giles and Ms. Wilson's mishap. He is pressed for time because he has a regular job as a second shift foreman. *(investigator model)* Being a trained MEDA investigator, his boss told him to identify the contributing factors and recommend strategies to prevent the mishap in the future. *(human error model, investigative purpose)*
>
> Fred interviewed both Mr. Giles and Ms. Wilson. Fred, being a second shift supervisor, found the cause of the mishap to be Mr. Giles failure to complete non-routine work performed on the first shift. *(perceptually salient stimuli, group self-serving bias, investigative style)* Fred's only explanation is that Mr. Giles became complacent toward

> compliance with the rules. *(representative causes)*
>
> Fred had heard that Mr. Giles and Ms. Wilson had some kind of off-work association; however, Fred believed that what happens outside work is of no interest to a company mishap investigation. *(natural stop rule)* Additionally, Fred heard that Mr. Giles had said that he would leave it up to Ms. Wilson to figure out what to do. Nevertheless, it was to him only hearsay and he was not going to ask a technician on another shift about such statements. *(natural stop rule)*
>
> Fred instructed Ms. Wilson to remember the leak check next time. Fred did not list it as causal on the investigation record because the mishap would not have occurred if Mr. Giles had given a good turnover report. *(discounting)*

Once this process has been completed, Fred would articulate what he believes to be the cause or contributing factors to this mishap. Should Fred be using MEDA, the final MEDA contributing factors list might have identified one contributing factor and the following description:

> √ *BOREDOM/COMPLACENCY: First shift technician did not record that additional clamps were loosened. Failure to follow general maintenance manual procedure.*

From what is known in the earlier full narrative, this mishap conclusion leaves much to be desired. Whether the investigator is completing a MEDA report or is merely briefing his management on the cause of an event – this explanation is unhelpful. It has taken the error identification one step further, yet it does not include many details of cause and effect relationships that might further enhance system safety.

2.10 APPENDIX B SURVEY INSTRUMENTS

October 18, 1998

Dear Aviation Colleague,

As you are likely aware, the US Federal Aviation Administration conducts maintenance human factors research in order to improve the safety of our aviation system.

I respectfully request your participation in one of these research projects intended to better understand our industry's process for developing causal explanations in response to human error events. That is, when a technician or manager makes an error, how do we investigate and what possible explanations exist for why the mishap occurred.

Enclosed are three surveys that will take approximately 30 minutes to complete. Each contains a short narrative of a mishap and three questions pertaining to WHY the mishap occurred.

Once you have read the first scenario (I recommend reading it twice), go to the second page and describe why you think the mishap occurred. Your task is NOT to determine which is easiest to fix or to decide who is to be blamed. Rather,

Your task is to simply judge WHY these particular mishaps have occurred.

Once you have completed the survey, please return the survey to me in the enclosed self-addressed envelope.

On behalf of the maintenance human factors research program, I thank you in advance for your participation.

Sincerely,

David Marx
Systems Safety Consultant

David Marx Consulting
W5440 Elkhorn Drive
Elkhorn, Wisconsin 53121
Tel: (414) 742-4874
Fax: (414) 742-4875
E-mail: davidmarx@davidmarx.com

Demographic Data

Name	______________________
Title	______________________
Organization	______________________
Telephone number	______________________
Years in Industry	______________________
Have you been through any Human Factors or Crew Resource Management Training?	______________________
Have you been trained as a human error investigator?	______________________ (Yes or No)
If so, on what error investigation system?	______________________
Are you an active error investigator?	______________________ (Yes or No)
If so, approximately how many human error investigations have you conducted?	______________________

Note: All data will be de-identified as to the person and the air carrier. Your name is requested in case any follow-up is needed. Please note that your data cannot be used unless the information above is provided.

Denver Ground Damage - Scenario A1

On December 22, 1997, an A-300 aircraft was inadvertently towed into Gate C14's jetway at Denver International Airport.

The aircraft was out of service for 14 hours and the repair to the wing cost $28,000 dollars.

Just before the mishap occurred, Ground Agent Smith was working on an airplane at gate C18. Ground Agent Smith had just spent 5 minutes unsuccessfully trying to start a tug at gate C18. At that point Supervisor Baker told Ground Agent Smith that a tug was available at gate C22. Ground Agent Smith ran over to gate C22 and found the tug running. He jumped in and backed up the tug toward the terminal. Unfortunately, the tug had been hooked to the aircraft by a ground agent at gate C22. When Ground Agent Smith pulled away, he took the aircraft with him about four feet before the wing hit the jetway.

The investigation found that the airline was having financial troubles and tug repair and maintenance had been deferred on much of the ground equipment. As a result, many of the tugs had trouble starting on extremely cold days; hence, Ground Agent Smith was delayed and had to rush to another gate to borrow a tug.

It was found that the airline's financial troubles resulted from a marketing error when the marketing department decided last summer to focus on discount holiday travelers at the expense of higher profit business travelers. Because of the financial troubles, preventative maintenance was reduced on the tugs.

Ground Agent Smith said that he would normally have checked to see that the tug was connected, however, he was extremely fatigued after working 14 hours straight and volunteered that he had been careless.

At the end of Ground Agent Smith's regular shift, Supervisor Baker approached Ground Agent aSmith and asked if he would be willing to work a second shift. Supervisor Baker had just come on herself and found that she was short two ground agents. Ground Agent Smith told Supervisor Baker that he did not believe that working a second shift was a good idea because he did not sleep well the night before. Supervisor Baker nonetheless encouraged Ground Agent Smith to work the extra shift.

Because of a rash of fatigue-related mishaps at this carrier, all Supervisors were once required to go through specific training on the detrimental effects of fatigue. However, Supervisor Baker was a new supervisor and because of budget cuts, Ground Operations Executive Brown decided to suspend all safety training. Had Supervisor Baker been trained, she would likely have asked Ground Agent Smith to go home after his first shift.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

____

____

The second most influential contributor to his mishap:

____

____

The third most influential contributor to this mishap:

Is there a “root” cause to this mishap? If so, what is it?

Denver Ground Damage - Scenario A2

On December 22, 1997, an A-300 aircraft was inadvertently towed into Gate C14's jetway at Denver International Airport.

The aircraft was out of service for 14 hours and the repair to the wing cost $28,000 dollars.

Just before the mishap occurred, Ground Agent Smith was working on an airplane at gate C18. Ground Agent Smith had just spent 5 minutes unsuccessfully trying to start a tug at gate C18. At that point Supervisor Baker told Ground Agent Smith that a tug was available at gate C22. Ground Agent Smith ran over to gate C22 and found the tug running. He jumped in and backed up the tug toward the terminal. Unfortunately, the tug had been hooked to the aircraft by a ground agent at gate C22. When Ground Agent Smith pulled away, he took the aircraft with him about four feet before the wing hit the jetway.

The investigation found that the airline was having financial troubles and tug repair and maintenance had been deferred on much of the ground equipment. As a result, many of the tugs had trouble starting on extremely cold days; hence, Ground Agent Smith was delayed and had to rush to another gate to borrow a tug.

It was found that the airline's financial troubles resulted from a marketing error when the marketing department decided last summer to focus on discount holiday travelers at the expense of higher profit business travelers. Because of the irresponsible actions of the marketing department, preventative maintenance was reduced on the tugs.

Ground Agent Smith said that he would normally have checked to see that the tug was connected, however, he was extremely fatigued after working 14 hours straight.

At the end of Ground Agent Smith's regular shift, Supervisor Baker approached Ground Agent Smith and asked if he would be willing to work a second shift. Supervisor Baker had just come on herself and found that she was short two ground agents. Ground Agent Smith told Supervisor Baker that he did not believe that working a second shift was a good idea because he did not sleep well the night before. Supervisor Baker nonetheless carelessly pressured Ground Agent Smith to work the extra shift.

Because of a rash of fatigue-related mishaps at this carrier, all Supervisors were once required to go through specific training on the detrimental effects of fatigue. However, Supervisor Baker was a new supervisor and because of budget cuts, Ground Operations Executive Brown decided to suspend all safety training. Had Supervisor Baker been trained, she would likely have asked Ground Agent Smith to go home after his first shift.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

____

____

The second most influential contributor to his mishap:

____

____

The third most influential contributor to this mishap:

____

____

Is there a “root” cause to this mishap? If so, what is it?

____

____

Phoenix Depressurization - Scenario B1

In April 3, 1998, a 757 had to turn back to Phoenix Sky Harbor Airport because it was unable to fully pressurize the cabin. It was found that two bleed air duct clamps were not tightened during previous maintenance, allowing pressurized air to escape into the engine compartment.

The outbound flight was delayed 8 hours because of the air turnback and the subsequent rework.

Technicians Giles and Wilson were the maintenance technicians involved in the prior maintenance at Sky Harbor. Technician Giles works first shift and Technician Wilson works second shift. Earlier in the day, Technician Giles was asked to troubleshoot a pressurization fault on the inbound flight into Phoenix. Technician Giles isolated the fault to a bleed air valve on the left engine. Following the maintenance manual, Technician Giles began to remove the bleed air valve. Technician Giles found the valve difficult to remove, so he loosened two additional bleed air duct clamps to add flexibility to the duct assembly. As the work was not complete at the end of his shift, the task was turned over to Technician Wilson who completed the work, although without tightening the two loosened clamps.

Investigation revealed that the aircraft maintenance manual did not reflect that removal of the two added clamps would significantly ease disassembly of the valve installation.

Because of the larger bleed air valve installed on the engine as a post-delivery modification, Technician Giles has to loosen the two additional clamps.

Although the proper course was to prepare a non-routine work order documenting the added removal, line maintenance technicians were encouraged to deviate from the manual instructions to get the job done. Although the deviation is a violation of Federal Aviation Regulations, management felt there would be no harm.

When it came to the shift turnover to Technician Wilson, Technician Giles simply forgot to inform Technician Wilson of the added disassembly.

Not knowing of the two added clamps being loosened, Technician Wilson dispatched the aircraft with the clamps still loose.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

____

____

The second most influential contributor to his mishap:

____

____

The third most influential contributor to this mishap:

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Is there a “root” cause to this mishap? If so, what is it?

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Phoenix Depressurization - Scenario B2

On April 3, 1998, a 757 had to turn back to Phoenix Sky Harbor Airport because it was unable to fully pressurize the cabin. It was found that two bleed air duct clamps were not tightened during previous maintenance, allowing the pressurized air to escape into the engine compartment.

The outbound flight was delayed 8 hours because of the air turnback and the subsequent rework.

Technicians Giles and Wilson were the maintenance technicians involved in the prior maintenance at Sky Harbor. Technician Giles works first shift and Technician Wilson works second shift. Earlier in the day, Technician Giles was asked to troubleshoot a pressurization fault on the inbound flight into Phoenix. Technician Giles isolated the fault to a bleed air valve on the left engine. Following the maintenance manual, Technician Giles began to remove the bleed air valve. Technician Giles found the valve difficult to remove, so he loosened two additional bleed air duct clamps to add flexibility to the duct assembly. As the work was not complete at the end of his shift, the task was turned over to Technician Wilson who completed the work, although without tightening the two loosened clamps.

Investigation revealed that the aircraft maintenance manual did not reflect that removal of the two added clamps would significantly ease disassembly of the valve installation.

Because of the larger bleed air valve installed on the engine as a post-delivery modification, Technician Giles has to loosen the two additional clamps.

Although the proper course was to prepare a non-routine work order documenting the added removal, line maintenance technicians were encouraged to deviate from the manual instructions to get the job done. As long as the added work was remembered, management felt there would be no harm in the deviation.

When it came to the shift turnover to Technician Wilson, Technician Giles simply forgot to inform Technician Wilson of the added disassembly.

Not knowing of the two added clamps being loosened, Technician Wilson dispatched the aircraft with the clamps still loose. In doing so, Technician Wilson violated company standards of conduct and Federal Aviation Regulations that prohibit a technician from dispatching an aircraft in an unairworthy condition.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

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The second most influential contributor to his mishap:

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The third most influential contributor to this mishap:

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Is there a “root” cause to this mishap? If so, what is it?

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Chicago Oil Loss - Scenario C1

On February 12, 1998 a 767 aircraft departed Chicago O'Hare destined for London's Heathrow Airport. Approximately 30 minutes into the flight, the right engine indicated low oil level. The aircraft declared an emergency and diverted to Detroit International Airport. Upon inspection in Detroit, technicians found that the right engine oil filler panel was left open, the oil cap was off, and oil residue coated the inside of the engine cowl.

The aircraft was out of service for 3 hours to clean up the mess.

In Chicago, Technician Swimmer was the only technician involved in the mishap. As the result of an aircraft swap at the last minute, Technician Swimmer was asked by Supervisor Jones to top off the oil on both engines and record the amount of oil added to both engines. Having added oil to both engines, Technician Swimmer ran up to the flightdeck to record the oil added, and then ran back down to the engines to install the oil caps and close the oil panels. When he arrived back on the tarmac, he installed the oil filler cap on the left engine but did not install the cap on the right engine.

Upon filling both engines with oil, Technician Swimmer was concerned that he would forget how much oil he had added to both engines. Because he had forgot his pen, the only way to write them down was to run up the flightdeck, borrow a pen from the captain, and make the entries directly into the log.

As Technician Swimmer was leaving the flightdeck, he received a call from his wife on his personal cellular telephone. She had just been arrested for driving under the influence of alcohol and was required per state law to spend the night in jail. Technician Swimmer's wife asked that he leave work as soon as possible to come get his children who were also at the police station.

Technician Swimmer knew his wife had a drinking problem. Being a relatively passive person, Technician Swimmer chose not to actively address the problem, hoping it would somehow go away.

Once he had got the call from his wife, Technician Swimmer told Supervisor Jones that he was distraught and would have to leave soon. Had Supervisor Jones recognized Technician Swimmer's distress, she might have prevented the mishap by assisting Technician Swimmer with the task.

There was a service bulletin available to error-proof the engine oil cap. The service bulleting allowed air carriers to modify their aircraft to add a check valve on the oil filler stem. The check valve acts to prevent flow out of the oil filler stem when the cap is not installed. While the air carrier was aware of the fix, it had chosen not to implement the bulletin because it was not cost effective.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

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The second most influential contributor to his mishap:

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The third most influential contributor to this mishap:

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Is there a “root” cause to this mishap? If so, what is it?

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Chicago Oil Loss - Scenario C2

On February 12, 1998 a 767 aircraft departed Chicago O'Hare destined for London's Heathrow Airport. Approximately 30 minutes into the flight, the right engine fire warning annunciated. The aircraft declared an emergency and diverted to Detroit International Airport. Upon inspection in Detroit, technicians found that the right engine oil filler panel was left open, the oil cap was off, and oil residue coated the inside of the engine cowl.

The aircraft was out of service for 3 hours to clean up the mess.

In Chicago, Technician Swimmer was the only technician involved in the mishap. As the result of an aircraft swap at the last minute, Technician Swimmer was asked by Supervisor Jones to top off the oil on both engines and record the amount of oil added to both engines. Having added oil to both engines, Technician Swimmer ran up to the flightdeck to record the oil added, and then ran back down to the engines to install the oil caps and close the oil panels. When he arrived back on the tarmac, he installed the oil filler cap on the left engine but did not install the cap on the right engine.

Upon filling both engines with oil, Technician Swimmer was concerned that he would forget how much oil he had added to both engines. Because he had forgot his pen, the only way to write them down was to run up the flightdeck, borrow a pen from the captain, and make the entries directly into the log.

As Technician Swimmer was leaving the flightdeck, he received a call from his wife on his personal cellular telephone. She had just been arrested for driving under the influence of alcohol and was required per state law to spend the night in jail. Technician Swimmer's wife asked that he leave work as soon as possible to come get his children who were also at the police station.

Technician Swimmer knew his wife had a drinking problem. Being a relatively passive person, Technician Swimmer chose not to actively address the problem, hoping it would somehow go away.

Once he had got the call from his wife, Technician Swimmer told Supervisor Jones that he was distraught and would have to leave soon. Had Supervisor Jones recognized Technician Swimmer's distress, she might have prevented the mishap by assisting Technician Swimmer with the task.

Because of a history of oil cap-related errors, the Federal Aviation Administration has issued an Airworthiness Directive requiring air carriers to modify their aircraft to add a check valve on the oil filler stem. The check valve acts to prevent flow out of the oil filler stem when the cap is not installed. In error and in violation of the Airworthiness Directive, the air carrier inadvertently failed to make the modification to the subject aircraft.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

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The second most influential contributor to his mishap:

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The third most influential contributor to this mishap:

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Is there a “root” cause to this mishap? If so, what is it?

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CHAPTER 3
IMPROVING OPERATIONS AND OVERSIGHT OF CONTRACT MAINTENANCE

Raymond P. Goldsby, Senior Aviation Specialist
Galaxy Scientific Corporation

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

3.1 EXECUTIVE SUMMARY

This study reports on the operational and regulatory challenges faced by "third party" (3rd Party), or contract repair stations, that provide intermediate and heavy level airframe maintenance for Federal Aviation Regulations (FAR) Part 121 certificated air carriers. Current operations, personnel, human factors, training, qualifications, documentation processes, job/task sign off issues and problems were examined. Federal Aviation Administration (FAA) oversight, surveillance and inspection of these operations were also reviewed. In addition, the relationships between aircraft operators (air carriers) and their contract maintainers were evaluated for potential issues and problems.

This research was accomplished by visiting major repair station sites and Flight Standards District Offices (FSDOs) over a cross section of the country. Altogether seven repair stations and FSDOs were visited, and over sixty people were interviewed. The researchers met and spoke with groups and individuals at the operations level of both major repair stations and the FAA. The findings and this report are based on those discussions and observations. By design, the research method and reports is not meant to be a statistical analysis. Instead, it is a "grass roots" investigation of what is actually going on in the day-to-day operation of the domestic 3rd Party contract maintenance business.

Oversight of 3rd Party contract maintenance has improved dramatically since the ValuJet accident in May of 1996. A United States General Accounting Office (GAO) report to Congressional Requesters, entitled *Aviation Safety – FAA Oversight of Repair Stations Needs Improvement*, was released in October of 1997 and was critical of the FAA's inspection and oversight of 3rd Party repair stations. Several recommendations were made based upon the GAO's findings and evaluation. The majority of these recommendations relating to inspection and oversight of repair stations have been implemented by the FAA; some were in progress prior to the report being distributed, others have been accomplished, some are still in various stages of implementation.

The inspection and oversight process is working well. FAA field operations are accomplishing the objective of ensuring that aviation maintenance is being carried out safely within the established rules and regulations. Air carriers and repair stations are ensuring that the air carrier's manuals, task documentation, procedures and processes are being followed. The relationships between the FAA field operations staff, the Principal Maintenance Inspectors (PMIs), the Aviation Safety Inspectors (ASIs), with some rare exceptions, are generally good to excellent. Are there issues and challenges within this process? Can improvements be made? Are there some problems and challenges that need to be addressed? The answer to these questions is, yes. However, the system is functioning well, continuously improving, and working to ensure regulatory compliance and aviation safety in the various maintenance facets of the industry.

The issues and problems that do exist are primarily systemic, having to do with the clarity and uniformity of FAA's management processes and oversight. These opportunities for regulatory improvement range from internal communications, varied interpretation of rules and regulations, autonomy of Regions and FSDOs, and the evolving regulatory review and change process. It creates a climate where many in industry feel they must constantly struggle to conduct business in this sometimes strained and ill-defined environment. These factors and non-uniform oversight situations have the potential to drive up the cost of doing business at an aircraft maintenance facility. Further they can lead to inefficient and costly regulatory oversight.

It is apparent that significant changes have been made based upon the lessons learned from the ValuJet accident. The errors made that caused the system to breakdown and created the chain of events that contributed to this accident have been addressed, eliminated, and/or corrected. However, there are no guarantees that the changes made, along with the increased level, frequency, and improved quality of FAA oversight and inspections will prevent such an accident from occurring again.

Despite these changes, there is much that remains to be done to update the FAA's operations systems, processes, and internal communications. There has been little progress to streamline the regulatory change and review process. Other nations are able to make significant progress in the area of regulatory change while the US has moves very slowly with maintenance regulatory action. Determining how to address and solve the existing issues and problems is not a simple task. Political oversight and special action committees have not been effective at changing rules. FAA continues to apply its limited appointed and career staff to identify and solve challenges that are presented in this report.

3.2 INTRODUCTION

A dramatic increase in outsourcing of air transport category maintenance has occurred over the past ten years. Outsourcing to 3rd Party maintenance providers (large FAR Part 145 Certificated Repair Stations) allowed aircraft operators world wide to reduce costs and focus on their core business. Operating under FAR Part 145, major repair stations do not have the same level of specific and detailed requirements for certification, training, maintenance programs, documentation, work cards, and organization structure as the air carriers who operate under FAR Part 121. Repair station maintenance staff differ significantly from those in air transport, in that the majority of those working in repair stations are specialists, of whom slightly over half are Airframe and Powerplant (A&P) certificated. Another element of repair station staffing, due to the fluctuating nature of workloads, is the emergence of a large pool (estimated to be in the range of 3,500 to 4,500) of maintenance personnel who work for temporary placement organizations ("4th party"). These organizations supply technician staffing to repair stations, allowing them to meet peak workload demands. These "contractors" move from one organization to another as needed, and have become a significant work force within the 3rd Party maintenance environment.

Maintenance visits to major 3rd Party repair stations include major overhaul (D checks), major periodic maintenance (C checks), major modifications and/or retrofits (passenger to cargo conversions and installation of noise reduction "hush" kits). Other work involves sale/lease preparation and lease return (operator to operator, leased aircraft owner to owner, often involving multiple countries with differing regulations and operating rules) and configuration changes. In addition, interior refurbishment, damage repairs (ground damage), out of phase major component changes (landing gear, etc.), and exterior painting may also be accomplished.

The basic elements of aircraft maintenance have changed little over the years. However, where maintenance is accomplished and by whom has and will continue to change. 3rd Party maintenance is one of, if not the fastest growing sector in aviation maintenance. Industry growth, coupled with increased maintenance workloads, has created challenges for the regulator. Add to this dramatic change in where maintenance is accomplished and by whom, plus rapid advances in technology, then all of the elements for problems that can challenge the FAA Aviation Safety Inspection program are in play.

A United States General Accounting Office (GAO) report to Congressional Requesters, entitled *Aviation Safety – FAA Oversight of Repair Stations Needs Improvement*, was released in October of 1997. This report was prepared as a result of heightened public and congressional interest in 3rd Party Aircraft Maintenance, generated by the preliminary NTSB findings from the May 1996 Value Jet Flight 592 "Everglades accident." The GAO report was critical of the FAA's performance in the area of 3rd Party Part 145 Certificated Repair Station oversight and inspections. It was specifically critical of the FAA's ability to ensure compliance at large repair stations.

The purpose of this project is to continue research and evaluation of the "3rd Party," or contract repair station operations, that provide intermediate and heavy level airframe maintenance. Current operational, personnel, human factors, training, qualifications, documentation processes, job/task sign off issues and problems were examined. FAA oversight, surveillance, and inspection of these operations were reviewed to determine to what extent issues and problems exist. The relationships between aircraft operators (air carriers) and contract maintainers were also evaluated.

Dr. Colin G. Drury examined job documentation processes and job/task sign off issues. His report, *Development of Process to Improve Work Documentation of Repair Stations*, is closely related to this project. Research for both projects was conducted, in part, during simultaneous team visits to major 3rd Party repair stations and FAA offices. The combined discussions and observations provided for full spectrum analyses of "shop floor" operations while they were in progress.

Training and qualifications issues were researched and summarized in the report released in April of 1998 by the FAA Office of Aviation Medicine (AAM-240) Aviation Maintenance & Inspection Human Factors Research Program entitled *Comparative Study of Personnel Qualifications and Training at Aviation Maintenance Facilities.*

The primary focus of this specific research is FAA oversight, surveillance, and inspection of major 3rd Party repair stations operations to determine the extent of any issues and problems that may exist. In addition, the relationships between aircraft operators (air carriers), 3rd Party repair stations with whom they are contracting, and the FAA were also evaluated for potential issues and problems. This research is not an evaluation of the overall FAA Aviation Safety Inspection Program. It is an overview of the current state of the inspection program in major 3rd Party Certificated Repair Stations and the relationships that exist between those parties.

Site visits were conducted at seven major 3rd Party Certificated Repair Stations located across the United States. In addition, four FSDOs were visited at locations close to the appropriate repair stations. In order to obtain objective, candid comments from the individuals contacted, their names and specific sites visited are held in confidence. Over sixty individuals were interviewed, both formally and informally, specifically for this research. Some of the repair station and site FAA visits were co-conducted with Dr. Drury. His report, mentioned above, focuses on job task documentation and related errors, along with recommendations for improvements. It should be considered, in addition to this report, to gain a wider perspective of repair station/FAA issues.

3.3 AVIATION MAINTAINERS

Before proceeding further with the details of this report, a discussion of the paramount and basic findings evident in this and previous research is appropriate. Anyone who has been in the aviation maintenance industry for any length of time, or has spent time learning about the business, can come to only one conclusion: Aviation maintenance people are solidly dedicated to the safe operation of the equipment they maintain, to the crews that fly it and the travelers who put their trust in both. This holds true for all participants including owner/proprietors, corporate executives, regulatory personnel, managers, workers, and those who manufacture and build airframes, engines, components, appliances, and related materials. It is not a business in which it is easy to make large profits, high-end wages, or quick and extensive capital gains. There is an old adage in aviation maintenance, "Do you know how to make a small fortune in aviation maintenance? Start with a large fortune!" It is an industry in which the vast majority of its members are hard working, dedicated, safety-minded people. Unfortunately, as in all businesses, there is an occasional rogue or "bad apple" who degrades the reputation of this majority, fortunately they are rare.

The people in the "trenches" at the major repair stations, A&P echanics, Repairmen, and the non-certificated specialists, are solidly committed to aviation safety. These people abhor aviation accidents and do their absolute best to avoid making errors. They are the base line, the personnel who interpret the documentation, complete the tasks and sign off their work. Under FAA certification they exercise the privilege to perform maintenance, as well as the management of the organizations where they are employed. They rely on the FAA for effective regulations. They also rely on the FAA to provide reasonable oversight to ensure compliance with those regulations. They depend on their management to provide them with the documentation, special equipment, training, qualifications, and leadership aligned with the regulatory requirements.

3.3.1 Industry and FAA Comments (Direct Quotes)

At the end of each section of this report there are a few selected direct quotes from industry and FAA personnel who participated in the interviews. These quotes are offered to show the opinions of interviewees. The quotes do not necessarily represent the opinion or recommendations of the report author, Galaxy Scientific Corporation, or the Office of Aviation Medicine.

> The FAA is an extra set of eyeballs; we have the same goals, viewed from different perspectives. They don't conduct surveillance and inspections to make repair stations honest, they do it to help them stay honest.
>
> The FAA has the same objectives as ours, aviation safety. They are simply a different set of eyeballs with a different point of view.
>
> Performance is the thing, no cutting corners here. The old adage, "pay me now or pay me later" is especially true in our industry.
>
> The Aloha accident was the wake up call; ValuJet was an even louder alarm! There have been many changes resulting from these accidents, the large majority of them are positive.
>
> Outsourcing will continue to grow. It will grow at a faster rate than the rest of the industry. It is up to everyone involved to make sure it grows safely.

3.4 THE ISSUES

One of the cost effective business trends in today's airline environment is outsourcing. At the center of this trend is the core business issue. Many carriers have elected to place primary focus on their core business of marketing, filling and moving airline seats from point A to B. The carriers that conduct this core business most successfully are those that carry the highest number of passengers at the lowest overall cost.

It is possible in today's environment for air carriers to own nothing, outsource everything, except passenger related operations, and in fact become "virtual airlines." One major area of outsourcing activity is aircraft maintenance. Outsourcing of maintenance has several advantages, especially for start- up carriers with limited infrastructure. It is a purchased service that provides lower overall cost than accomplishing the same work in house. At the end of the day, after the primary responsibility of ensuring that all safety standards and requirements have been met, the air carrier's second responsibility is the cost effectiveness required to maintain competitive operations.

The operational environment at a large FAR Part 145 Repair Station is significantly different from a

FAR Part 121-Certificated Air Carrier. These differences create both advantages and disadvantages for the industry. Some of the major differences are:

- Maintenance workload is more predictable in the air carrier environment than at a 3rd Party repair station. An airline has control of fleet size, fleet mix, aircraft hours, cycles, maintenance plans, and aircraft routing. With these known factors, planning for workforce staffing, facilities allocation, and all contingent operations can be controlled reasonably well. If there is a workload overflow, it can be outsourced. A 3rd Party repair station, on the other hand, has limited control over these elements. Workload varies with customer demands; contracts come and go, there is limited control over fleet mix, work content and amount. Staffing, therefore, is variable, as is facility use and space management. Maintaining costs at competitive levels while keeping a stable, trained and qualified workforce is a challenge. This variability is met by maintaining a core workforce and bringing in temporary contract workers to meet any shortfall.

- While some air carriers accomplish limited amounts of aircraft maintenance for other carriers, their primary effort and main focus is placed on their own fleet. They operate under one FAA approved (their own) General Maintenance Manual (GMM), produce and maintain their own work documents and deal directly with the aircraft manufacturer for technical information and support. A repair station operates under its own FAA approved GMM and must also comply with each customer's FAA approved GMM. They have their own job documentation and most often mix it with different job documents from each customer.

- Technical data exchange is often a challenge for 3rd Party repair stations. The air carriers are linked directly with the original equipment manufacturer (OEM) or manufacturer for technical data as part of aircraft purchase agreements. The repair stations most often do not have such access and must rely on their customers for necessary technical information. Parts and components support is frequently a similar issue, the repair station is dependent upon their customer carriers to provide parts and components.

- Personnel training and qualification, along with the required record keeping, is a significant task for air carriers. Since most carriers have large computer systems, training and qualification (T&Q) records are maintained as complex electronic databases. These electronic T&Q systems allow carriers to maintain, access, sort and analyze data quickly and effectively. The repair stations have significantly less computerization and automation on hand. In most cases training and qualification records are manual entry and paper based, or simple computer software spread sheets. Since workload and fleet type are subject to frequent changes, training record maintenance is a challenge, especially on the job training records, which serve to verify a worker's task(s) currency and/or competency.

- Air carriers operate under the surveillance of FAA Certificate Management Offices (CMO). Aviation Safety Inspectors (Airworthiness) (ASI) who are often experienced in FAR Part 121 operations, and are usually responsible for a single carrier, staff CMO offices. Certificated Repair Stations operate under the surveillance of Flight Standards District Offices (FSDO). According to those interviewed, these offices are often staffed by personnel who are most familiar with general aviation; fewer office personnel have large air transport operations experience. Staffing increases in the ASI workforce place new inspectors in offices by seniority, this often places the new inspectors in FSDOs at "less desirable" locations. Frequently, the so-called "less desirable" locations are where the largest concentration of major 3rd Party repair stations are located.

Major repair station operators have many challenges and must serve more than one airline. They are responsible for their own operational requirements, the requirements of individual customers, and for working several models of aircraft from different manufacturers. In addition, they are legally bound to oversight from a regulator whose inspectors are from both customer CMOs and local FSDOs and who, at times, provide variable interpretations of the same rules.

These issues, plus a few of lesser impact, are addressed in this report. Knowing that these issues are part of the repair station environment should not lead one to believe that the environment has negative impact on aviation safety. It serves to point out, however, that there are problems that create more complexity in maintenance operations at major certificated repair stations than may be obvious to the casual observer.

3.5 THE GENERAL ACCOUNTING OFFICE 1997 REPORT

The 1997 GAO Report *Aviation Safety – FAA Oversight of Repair Stations Needs Improvement* provides issues that were reviewed in part for this research. The following issues were defined in the document as part of the Executive Summary - Principle Findings:

Current Inspection Approach Limits FAA's Ability to Ensure Compliance at Large Repair Stations

Most of FAA's offices use the approach of assigning an individual inspector to a repair station, even one that is large and complex, rather than assigning a team of inspectors. Although this one-inspector approach constitutes FAA's primary frontline surveillance of repair stations, each year regional and national decisions are made to use teams for more comprehensive reviews of a few repair stations. When direct comparisons could be made, teams were shown to be more effective than individual inspectors in identifying those areas in which repair stations were not in compliance with FAA's rules and regulations, even if one inspector visited the facility several times and the team visited it just once. GAO reviewed 19 instances in which large repair stations inspected by one person had also been inspected by a special team during the same year. These special inspections are conducted at selected facilities that FAA regards as needing additional attention. The teams found a total of 347 deficiencies, only 15 of which had been identified in all of the visits made by individual inspectors in the year or more leading up to the special inspections. Deficiencies the teams identified included many that were systemic and apparently long-standing, such as inadequate training programs or poor manuals for quality control. Such deficiencies were likely to have been present when the repair stations were inspected earlier by individual inspectors.

There are several reasons why team inspections identify a higher proportion of the deficiencies that may exist in the operation of large repair stations. Teams are better than individuals at ensuring that the inspection covers all areas of operations and that inspectors stay focused on the task at hand. Many FAA inspectors responsible for conducting inspections on their own said that because they have many competing demands on their time, their inspections of repair stations may not be as thorough as they would like. Another reason is that team inspections make greater use of checklists or other job aids for ensuring that all points are covered. FAA's guidance requires inspectors to address all aspects of repair stations' operations but does not prescribe any checklist or other means for specifying the items to be covered. The lack of a standardized approach increases the possibility that items will not be covered. Finally, inspectors believe team inspections help ensure that their judgements are independent because most team members have no ongoing relationship with the repair station. By contrast, individual-inspector reviews are conducted by personnel who have continuing regulatory responsibility for the facilities.

A few of FAA's offices have recognized that the traditional approach of relying on one inspector may be inadequate for overseeing the operations of large repair stations and have reconfigured their inspection resources to do more team inspections without adversely affecting other duties. They have done so mainly by redirecting the time formerly spent on reviews by individual inspectors into more systematic inspection's done by a team of local, in-house staff. GAO identified FAA offices in Scottsdale, Arizona; Miami, Florida; and Seattle, Washington, as having initiated such changes on their own. FAA headquarters officials acknowledge and support these offices' initiatives. They said they believe these initiatives need to be evaluated and, if appropriate, used at other offices.

Follow –Up and Documentation Need Attention

FAA's guidance is limited in specifying for inspectors what documents pertaining to inspections and follow-up need to be maintained in repair station files. The closest thing to a requirement is a statement in the Airworthiness Inspector's Handbook that the deficiency letter FAA sends to the repair station describing all deficiencies should be included in the repair station case file. GAO examined records of 172 instances in which FAA sent deficiency letters to domestic repair stations. The responses from the repair stations were not on file in about one-fourth of these instances, and FAA's assessments of the adequacy of the corrective actions taken by the repair stations were not on file in about three-fourths of the instances. GAO also examined computer-based reports summarizing inspection information for FAA managers and found these reports were even less complete. Without complete documentation, it was impossible to assess how completely or quickly repair stations were bringing themselves into compliance.

Better documentation is needed not only to allow FAA to demonstrate how quickly and thoroughly repair stations are complying with regulations, but also because it can affect FAA's ability to identify performance trends involving the inspection of repair stations and to make informed decisions about them. FAA is developing a reporting system that, among other things, is designed to use this documentation to make decisions on applying inspection resources to those areas posing the greatest risk to aviation safety. Such a system will be of limited use if the documentation on which it is based is inaccurate, incomplete, or outdated. FAA must have data to show where safety problems and deficiencies exist and, thus, where to better target its limited inspection resources. In 1995, as part of a prior study examining FAA's information management systems, GAO recommended that FAA develop a comprehensive strategy for making data-related improvements. FAA agreed with GAO and has been implementing a number of improved data collection systems. FAA's On-line Aviation Safety Inspection System (OASIS) is a leading example of this progress.

Documentation of inspections and follow-up was better in FAA's files for foreign repair stations, perhaps in part because under FAA regulations, foreign repair stations must renew their certification every 2 years. By comparison, domestic repair stations retain their certification indefinitely unless they surrender it or FAA suspends or revokes it. Foreign repair stations appear to be correcting their deficiencies quickly so that they qualify for certificate renewal. The 34 FAA inspectors GAO interviewed who had conducted inspections of both foreign and domestic repair stations were unanimous in concluding that compliance occurred more quickly at foreign facilities. They attributed the quicker compliance to the renewal requirement and said that it allowed them to spend less time on follow-up, freeing them for other surveillance work. However, because of the poor documentation in domestic repair station files, GAO was unable to confirm whether foreign repair stations achieve compliance more quickly than domestic repair stations do.

Actions Under Way Directed Primarily at Air Carriers' Oversight of Repair Stations

A number of repair station initiatives, announced in June 1996 by the previous FAA Administrator, following the ValuJet crash are directed at clarifying and augmenting air carriers' responsibilities for overseeing repair stations. For example, one initiative requires that before an air carrier can add a repair station to the list of repair stations doing substantial maintenance on its aircraft, the carrier must conduct an audit to verify that the repair station is capable of doing the work in accordance with the carrier's approved programs. GAO did not directly assess the initiatives in this review because the initiatives are not focused on strengthening FAA's own inspection and follow-up efforts. FAA inspectors assigned to oversee repair stations told GAO that the initiatives would have no effect on their direct inspections of repair stations.

Several other efforts unrelated to the June 1996 initiatives may hold potential for improving FAA's own inspections of repair stations. Two involve initiatives to change the regulations covering repair station operations and the certification requirements for mechanics and repairmen. FAA acknowledges that the existing regulations do not reflect many of the technological changes that have occurred in the aviation industry in recent years. The FAA inspectors surveyed by GAO strongly supported a comprehensive update of repair station regulations as a way to improve repair stations' compliance. This update began in 1989, has been repeatedly delayed, and still remains in process. The most recent target – to have draft regulations for comment published in the Federal Register during summer 1997 – was not met. Similarly, the update of the certification requirements for maintenance personnel has been suspended since 1994. Because of these long-standing delays, completion of both updates may require additional attention on management's part to help keep both efforts on track. The third effort involves increasing FAA's inspection resources. Since fiscal year 1995, FAA has been in the process of adding more than 700 inspectors to its workforce who will, in part, oversee repair stations. Survey responses from current inspectors indicated that the success of this effort will depend partly on the qualifications of the new inspectors and on the training available to all those in the inspector ranks.

3.6 REPAIR STATION VISITS

Is the Aviation Inspection System improving? Has the FAA inspection program changed significantly since the 1996 ValuJet accident? Are major 3rd Party repair stations and FAA inspectors working as safety improvement teams? Have the issues stated in the 1997 GAO report been addressed? The answer to these questions is generally, yes. There was consensus that significant improvements in FAA oversight have been made over the past two years. Repair station personnel at all levels were cordial, cooperative and very candid with what they had to say interviews and discussions.

There was concern expressed by both repair station and FAA personnel over the so-called " Bean Counter" mentality. Some felt strongly that the tough competition between airlines to lower their costs per seat mile, if not carefully and objectively evaluated by maintenance professionals and monitored by the FAA, could have a negative effect on safety. There is always heavy pressure from airline corporate officials to "do more with less" along with the "better, faster, cheaper" motive for profit. "There is nothing wrong with profit, that's what the world economy is all about," said one repair station QA manager. "It's up to us guys in the trenches, working with the FAA, to keep them honest."

Though some aspects of the relationship with the FAA may be less than nominal, with only one exception, it was agreed that the inspection and regulatory oversight elements of the relationship are good to excellent. While progress is being made and positive steps continue to occur, areas remain where further improvements can be made.

3.6.1 Inspection Frequency and Effectiveness

The seven repair stations visited were unanimous in stating the number of FAA inspections have increased significantly. In some operations, prior to 1997 and early 1998, ASIs seldom visited the premises more than once or twice per year. Currently, at a minimum of once per year, repair stations are subject to National Aviation Safety Program Inspections (NASIP), consisting of teams with members from other FSDOs, Regions or CMOs. The NASIP inspections are conducted under a procedural format with written guidance and specific inspection tasks. The team spends several days in the operation being inspected; they are certainly not casual "drop in visits."

There were no serious issues nor problems found in six of the seven repair stations visited. Certainly, along with positive findings, some were less than positive. Several areas where improvements can be made were presented and discussed. In only one repair station, a separate topic in this report, were significant issues and problems with the FAA evident.

> Note: It was observed that in some 3rd Party repair stations, personnel safety practices and the hangar equipment used is well below the standards of air carrier maintenance. During these visits several potential OSHA violations and obvious safety infractions were observed. In pointing these out to repair station personnel they were asked if the FAA ever mentions on-the-job safety issues as part of their inspections and surveillance. The answer was: "almost never." The FAA was queried about this finding; the general response was that they did not have time to observe personnel/hangar safety and it is also the responsibility of another agency.

3.6.1.1 Comments from Repair Station Personnel (Direct Quotes)

Most issues are resolved in meetings with our PMI (Principle Maintenance Inspector) and ASIs. Sure, we still get a letter of investigation once in a while; as a result you get a better repair station.

We have an excellent relationship with our local PMI.

Working together and professionalism really showed with the 737 fuel pump wiring grounding AD (Airworthiness Directive).

If you are honest and straightforward with the FAA, they are usually the same with you; taking an adversarial position does not work well for either side.

The best inspectors are from the air transport industry. Some of those who are not tend to be out to make a name for themselves, and are often uninformed and ignorant of “big iron” operations.

We see our PMI or ASIs at least once each week and we have formal NASIP inspections at least once a year, usually more often. This facility has had no enforcement action for over 4 years… that’s positive for the FAA and us.

We seldom see our customer’s PMIs after their first visit. A major customer’s PMI (with whom we have a large multi year contract) visits about once a year.

We operate multiple facilities and have good relationships with the Region and all our FSDOs.

Since we operate primarily as a Military contractor, we don’t see the FAA very often. As we change to more civil air transport customers, the FAA will be here frequently. The FAA works with us like a “neighborhood policeman who walks a beat.” They are here to keep order; we know them, they know us and we respect each other.

We have no scheduled meetings with the FAA, but meet or talk with them 3 of the 5 work days each week.

The PMI should be on site once a week. Meetings would be a good idea and/or have them sit in on our Quality Assurance status meeting.

We had a recent paper work audit that was very productive. The FAA found errors, sat with our auditors and chief inspector to help us improve our processes. They stated clearly what the problems were and suggested how to fix them. There were no Letters of Investigation, just a good meeting of the minds and the clearing up of some paper work problems.

The PMI and his ASIs meet with us once a week in a formal process improvement meeting. We have an agenda, action items, goals, objectives and time lines. There have been several problems solved and errors corrected as a result of these meetings. Our organization feels that this team approach to oversight yields both good relationships and excellent results.

The frequency of FAA visits has increased and there is a good deal more surveillance.

We have excellent relationships with the FAA. We passed 3 NASIP inspections with only minor paperwork errors.

There are a few PMIs that need to micro manage, others who work as a team with their repair stations, and one or two who think they need to act like mean “motor” cops.

Our organization is primarily airline folks. We have a different book [view] on how to do things. Our primary customer is an airline that we have worked with for over 9 years, we all work well together. The customer, their PMI, our organization and PMI work very well together. We started 11 years ago with a “white glove” inspection and have passed our last 3 NASIPs with no findings other than minor paper work and manual problems.

Our repair station has more scrutiny than the airlines. We have our own strong QA organization, plus our PMI, the airlines PMIs and the QA groups from all the customers.

We considered ValuJet a wake up call. All of our parts now go through our stock room that is staffed by well-trained people with a double signature requirement on all documents.

Bean counters have had too much influence on the maintenance industry. The fact is that our organization is not run by bean counters. We are concerned about business, profit etc., and we also understand that true cost effectiveness is based in high safety and quality. We are only as good as the last airplane that left here.

The bottom line can be dangerous. “Bean Counters” are not only running airlines; they are running safety. An example is a 145-repair station accomplishing a letter check (A thru D) at a flat rate for routine work, with a x dollar cap for non-routine. This could be a very dangerous practice.

The PMI has the last word on the operation here.

Though a lot depends on individual ASIs and PMIs, if the repair station staff is honest and straightforward, the FAA will respond in kind. An adversarial position does not work well for either side.

3.6.1.2 Comments from FAA Personnel

We see no problems here; there are normal regulator/operator relations.

We know that the so-called bottom line will kill. Sometimes we have to fight with each other to make it right.

There is too much aviation for the numbers of skilled and qualified people who are properly certificated. There are too many who don’t know what they don’t know.

Sub, sub, sub, is a problem. The repair stations sub-contract work to others who often sub-contract part of the work sub contracted to them and so on. It becomes a real challenge to keep up with it all.

3.6.2 Air Carrier Oversight of Repair Stations

One FAA ASI said it very well; “outsourcing simply provides another hangar for an airline.” While several airlines have always maintained a keen interest in how their 3rd Party contract maintainers conducted their business, others have not. The actions taken by the FAA with revisions to the Inspectors Handbook 8300-10 and additional guidance and advisory materials have caused all air carriers to pay close attention to work being conducted for them by repair stations. It is now required that air carriers report substantial work done at major 3rd Party maintenance facilities to their Principle Maintenance Inspector (PMI) or Certificate Management Office (CMO). Each CMO now has an “R” item (formal recurring item) requirement to visit these repair stations to ensure regulatory compliance and to ensure the coordination of oversight from the customer carriers.

Some air carriers (Northwest was cited as an example) now have a section in their General Maintenance Manual (GMM) that speaks to the who, what, when, and how work is to be conducted by contract maintenance providers. The FAA FSDO people who provided this information suggest that this should be an industry wide requirement. In general the air carriers appear to have taken seriously the requirement to supervise maintenance operations conducted on their aircraft while being worked in 3rd Party repair stations. There were no problems indicated, airlines are taking responsibility for compliance with this requirement.

3.6.2.1 Comments from Repair Station Personnel (Direct Quotes)

We are not only under the surveillance of the FAA but also our airline customers. The airlines, with the increased emphasis by the FAA on their responsibility for work done by contractors, are more focused on our operations and how we perform work on their equipment.

Our Part 121 air carrier customers are very particular about their inspection and oversight of our operations. They are very thorough and we are very diligent in correcting any problems in order to make it right and keep the business.

3.6.2.2 Comments from FAA Personnel

> The airlines who were not paying attention to their work being done in repair stations are doing so now. All air carriers are now clear on their responsibility to ensure their documentation is being followed and that quality work is being accomplished at repair stations where their aircraft are being maintained or modified.
>
> With one of the airlines assigned to us, their contracting out has not been a pleasant experience. They were doing a poor job of overseeing and monitoring their 3rd Party maintenane providers.
>
> At times we have had problems getting operators to really accept the oversight responsibility. Clarification of the regulations has improved this area immensely.
>
> "Rent-a-Reps" [Maintenance Representatives] contracted by an air carrier to oversee their airplane(s) during maintenance at a repair station] are not tied into carrier's quality control. Air carriers should provide representatives based upon the type of work being done.
>
> Reps. tend to spent too much time in the office doing things other than ensuring the repair station is doing the work correctly, based upon their specifications, manuals and job cards.

3.6.3 Manuals, Documentation and Job Task Cards

Detailed information on this aspect of our research will be found in Dr. Colin Drury's report, *Development of Process to Improve Work Documentation of Repair Stations*. Certain elements Dr. Drury's report are germane to this project, because the maintenance documentation process creates challenges for repair stations, and their FAA inspectors.

The aircraft worked at repair stations are basically the same on a type by type basis. There are differences in various models and configurations within a type, but the basic airplane is the same or highly similar. This being true, no standards for common documents exist, nor are any required between airlines, repair stations and for that matter aircraft and component manufacturers. This means that repair stations are required to understand and conduct work based upon their own General Maintenance Manual, Operating Procedures and job task cards while at the same time working from the same document set provided by each customer. The repair station must follow each customer's maintenance plan, maintenance manuals, job task cards, and procedures.

There was consensus from all repair station personnel who participated in the station visits, the variance in documentation, manuals, and job task cards between customers is a major challenge. "Paper work" differences provide a significant area where errors can easily be made. There was not one repair station official who was not willing to participate in any sort of maintenance documentation standardization effort that the industry may mount.

3.6.3.1 Comments from Repair Station Personnel (Direct Quotes)

> Each customer has their own maintenance manuals, illustrated parts catalogs, structures repair manual, general maintenance manual, quality control procedures manual, maintenance proceedures, routine job cards and non-routine job cards. These documents are mixed with our general maintenance manual and our own job cards. Imagine, at one time we can have three or four customer aircraft in work, all of the same type and model, with a different set of paper work for each. Keeping all the documentation straight and correct is a real challenge. It is an area where it is easy to make errors if not very alert and careful.
>
> Mechanics with experience should be used to write job cards; there would be fewer errors, more productivity.
>
> Perhaps the 145s will help straighten out the 121's paper work. The 145s are forced to read it word for word.
>
> There is a strong need for standardization of maintenance documentation and job/task cards. The basic work package is so bastardized, yet the job/task content is 90% the same. Job cards should all be the same; differences could be handled in other documentation related to, but outside of, the actual work packages.
>
> It is a known fact that Simplified English reduces comprehension errors by at least half. The technology to convert all maintenance documents exists, why isn't its use a requirement. This is one area where the FAA could exert some influence.

3.6.3.2 Comments from FAA Personnel

> Maintenance documentation is an area we watch carefully. Since it is different for each manufacturer, air carrier, and repair station, we have to know and understand the differences. It is an area that needs attention and probably could use standardization.
>
> There should be a team effort to decide what needs to be in the General Maintenance Manual and also the Inspector's Handbook, 8300-10. Maintenance has gone global and clarification is needed.

3.6.4 Human Factors and Error Management Programs

Maintenance Human Factors, Maintenance Resource Management (MRM), and Error Identification and Management programs are recognized to have value in improving safety and overall performance. Most major airlines throughout the world have these programs in place. The 3rd Party repair stations, as a rule, are not nearly as far along as the airlines in developing Maintenance Human Factors and Maintenance Resource Management (MRM) programs.

The FAA, Office of Aviation Medicine has been conducting research in Maintenance Human Factors over the past 12 years and has produced a large quantity of valuable data, training programs, research papers, performance statistics and related materials. This information, including their *Human Factors Guide in Aviation Maintenance and Inspection* is available on both CD-ROM and the Internet. The Air Transport Association (ATA) has also recognized the need for these programs and has formed a Maintenance Human Factors Subcommittee, which is open to any interested party including non-ATA members. This ATA subcommittee has recently developed and released *ATA Specification 113 – Maintenance Human Factors Program Guidelines*.

There is only one major repair station that has made a significant effort, and have developed an exemplary program. This program could well be used as a model for all major repair stations, all the groundwork has been done and this organization is willing to share. They developed their program using the material available through the FAA Office of Aviation Medicine's Aviation Maintenance and Inspection Human Factors Research Program materials on the subject, and also worked with the Boeing Company and the Air Transport Association. There may be a few other repair stations that are in the process of starting programs without having made it known to the industry. However most repair stations visited had limited knowledge if any of Maintenance Human Factors and related programs. The 3rd Party repair station community is well behind the rest of the industry in this obviously important area.

The new aviation maintenance personnel certification rules from Transport Canada and the Joint Aviation Regulations in Europe and the United Kingdom include requirements for mandatory Maintenance Human Factors training programs. None of the US FAA's current rules or those under review or in process of revision, has any provision for Maintenance Human Factors programs and/or training as a requirement. This holds true even though at least one National Transportation Safety Board (NTSB) member strongly supports a Maintenance Human Factors regulatory requirement, and both the EEC and Transport Canada have made it mandatory.

NTSB Member John Goglia is a strong and avid supporter of Maintenance Human Factors and MRM programs. He has supported all activities, meetings, seminars, and symposiums possible, as both an attendee and speaker. Member Goglia, who is the only NTSB member to come through the ranks as an A&P Certificated Mechanic, strongly supports including Maintenance Human Factors as part of all FAA maintenance certification rules. His viewpoint simply stated; it costs a lot less for the industry to have a Maintenance Human Factors requirement than it does for one air carrier accident. Member Goglia questions why the FAA has not considered such an important element, in the improvement of aviation safety, as part of their rulemaking action.

These programs are being put in place voluntarily by the aviation industry because they improve safety through the identification and reduction of errors, finding root causes to prevent accident reoccurrence, and thus improve overall performance. They are not being funded and developed because they are "programs de jour" or the current business trend. Human Factors and error reduction programs are simply good business from any standpoint. It was interesting to learn that the FAA has no intention of including these sorts of programs as a requirement in any rule making. It was also obvious that the FAA personnel in the field are, for the most part, uninformed about the entire Maintenance Human Factors effort.

3.6.4.1 Comments from Repair Station Personnel (Direct Quotes)

Safety can be improved with formalized, expanded, self-disclosure. MEDA, or similar programs, gather error data that can be objectively analyzed. Problems and issues identified can be prioritized, evaluated and corrected.

Though we don't have a formal Human Factors program, we do some of those sorts of things. At the end of each aircraft visit we hold a team de-briefing to learn what we could have done better. We also follow the aircraft operational performance for the 30 post visit days, taking action to correct discrepancies that may have caused problems. These reports go to the President and Vice President for review, then into the aircraft's file.

Repair stations must be pro-active with error reporting and analysis. The FAA must be receptive and work together with us to solve problems and correct deficiencies.

Do we want MRM & MEDA, self-reporting and error disclosure to work or not? If we don't know what the problems are, we can't work toward solutions.

We here at the 145s don't respond well to LOIs (letters of investigation), official or unofficial.

3.6.4.2 Comments from FAA Personnel

Is there a human factors program? We don't know much about what Headquarters is doing, in the area of Maintenance Human Factors, out here in the field. We did not know that the Office of Aviation Medicine even had a program, we will take a look at their Web-site.

A lot of this error reporting business is just a way for the repair stations to avoid LOIs and violations. This human factors stuff is just a bunch of hooie thought up by some Ph.D. guys. When mechanics make errors they should not be able to report them to an error program, and by doing so avoid any action from the FAA.

3.6.5 Maintenance Personnel Training

Training at the 3rd Party repair stations has not changed for a number of years. It is still a function that meets, but at most repair station never exceeds the minimum standard. Training and qualifications issues were researched and summarized in the report released in April of 1998 by the Office of Aviation Medicine Aviation Maintenance and Inspection Human Factors Research Program (AAM-240) entitled *COMPARATIVE STUDY OF PERSONNEL QUALIFICATIONS AND TRAINING AT AVIATION MAINTENANACE FACILITIES*. Little would be served by restating the findings of that report here. In conducting this research, though maintenance training was not a focus, comments were made that reinforce the 1998 research findings.

3.6.5.1 Comments from Repair Station Personnel (Direct Quotes)

A training audit is on records and rosters only, never on training content, quantity or quality.

The FAA accepts 40-hour General Familiarization courses, provided by outside vendors, as satisfactory for work on a specific aircraft type. They don't look into the instructor's background nor review the training programs. We insist on instructors that are factory trained or those qualified as airline instructors. The FAA is too easy to satisfy in this important area.

Airlines will run required paper work and processes training for repair stations, usually free of charge.

The regulator will accept a "read and sign off" as an acceptable orientation program for a new hire repair station mechanic. This may be OK for an older, experienced hand, but most of our new folks are new folks.

We don't feel that reading the manuals is enough here; we have a good program taught by our own instructors.

3.6.5.2 Comments from FAA Personnel

No, we don't sit in to monitor classes at repair stations; there is not enough time.

We accept 40-hour general aircraft system familiarization courses as acceptable for repair station mechanics.

Most repair stations are doing a much better job in recording, training, and keeping acceptable records.

We accept a minimum standard without having a clear definition of what it is. As long as the maintainers have had some training and it's on record, we accept it.

3.6.6 FAA Inspector Training and Qualification

The training of Aviation Safety Inspectors (Airworthiness) is an area where both the FAA and Repair Station people agreed that improvement is needed. Unfortunately there were no raves for the ASI programs given at the FAA Academy in Oklahoma City. Most suggested that the best training is what's learned on the job and from what experienced FAA people can tell them.

Several comments pointed toward the need for more, higher quality, in depth, "real world and task focused" curriculum. This area was not explored in depth and the comments speak for themselves.

3.6.6.1 Comments from Repair Station Personnel (Direct Quotes)

Though the quantity has improved, there has been little improvement in the quality. This may be due to so many new inspectors on the job and what seems to be lower FAA hiring standards than in the past.

It would be good if the FAA could do a better job of matching an ASI's assignment to his or her background and experience. We have to train new ASIs if they are not 121 aircraft maintenance qualified. We have a program (mechanic entry internship) that lasts from 2 weeks up to 30 days. We only hire people who are successful in this program. We would be happy to include anyone from the FAA who may wish to attend.

We have to train the PMIs, there are just too many with very little or no experience at all.

ASIs tend to look for what they know, paper work or process.

We have frequent turn over in our PMIs; they only last about one year.

FAA's numerous manuals, rules, regulations, advisory circulars, and handbooks force ASIs and PMIs to make interpretations beyond their skill sets, educational levels and training base. Let's face it, the training given to FAA staff (travel on Monday, training on Wednesday through Thursday, and travel on Friday, causes the FAA training week to be only 24 hours) is simply not very good.

There should and could be joint training at the FAA Academy which includes the FAA, repair stations and their customers, the manufacturers and our vendors. This could be done so that we can work together to improve, establish and maintain continuous improvement in the aviation safety system. Take a look at the dramatic success of Boeing's 777 Working Together Program.

Sure some things have improved since ValuJet but others have not. Training for new ASIs must not be very comprehensive. We, the 145s, have to do a lot of training before these new folks have a clue as to what is going on. I know the FAA has lowered their hiring standards. Given the lower entry-level inspector qualifications, their training should be evaluated and re-developed accordingly. Why should the repair stations be training new ASIs? There is only one reasons, if we don't, no one else will.

3.6.6.2 Comments from FAA Personnel

More ASIs have been provided, most are new to the FAA but not to aviation. They are running them through Oklahoma City very quickly.

Our training has no standards. The rules are very vague giving us no solid foundation on which to conduct surveillance over the repair station and/or the airlines. There is a very high turn over rate, which adds to the problems.

3.7 FSDO VISITS

A number of visits to FSDOs were conducted and their leadership and management varied. Most of what was observed could be classified in a range from excellent to very good.

The Managers, PMIs, and ASIs take their jobs very seriously. Some of the offices are operated by leaders who appeared to be excellent managers, versed in modern team building and "working together" principles. Those who fostered the team and working together concepts were respected, if not admired, by both their staff and the repair station personnel they oversee. One FSDO in particular could be used as a model for establishing an FAA operational standard on how maintenance operations oversight could and should be managed.

While all the FSDO personnel were quick to state that there have been several improvements since the summer of 1996, they will also state that there are still some problems and issues that must be addressed. There was, however, unanimity that the problems with the aviation oversight system have been addressed and, if not completely fixed, are well on the way toward being solved. All were in agreement that aviation safety is in good hands, and that the regulator is successfully accomplishing maintenance and major repair station oversight

There was consensus in all offices visited that there is a big "disconnect" between the field and Washington Headquarters. There is also a level of disdain for the way the FAA is managed at the highest levels. Not only is it common to hear "we have no idea what is going on back there" but also, "we don't care what is going on back there." It's small wonder that both the repair stations and the FAA people in the field will state openly that the system is dysfunctional. This begs the question; is it any wonder why there are so many different interpretations of rules and regulations depending upon the Region, FSDO, and individual FAA person?

3.7.1 FAA Comments (Direct Quotes)

There has been a great deal of improvement since 1996. Too bad it had to happen by accident.

There are now 120 employees handling what 80 were responsible for prior to ValuJet. When at full staffing, there will be 130. It's great to have what it takes to get the job done.

Now that we have what we need, we will be doing the job we should. It has been a struggle, we are getting some new guys and gals that are really knowledgeable and professional.

We will have a new facility soon. All employees will have both the space and the tools they need to do an effective job.

ASIs in the field know what their job is. Most are focused on what they do. We have rules, advisory material, handbooks and procedures, if one follows them the job is straightforward. ASIs do what they are trained to do.

Things are really looking up in the FAA. It is a good job, good security and well paid. Most of the folks we work with are appreciative.

There seems to be good communication between regional offices. There is no turf issue with airline CMOs or ASIs. We all review the PTRS (Program Tracking and Reporting Subsystem). It is an excellent way to keep abreast of what others are doing, issues and problems in the field. The ASI from an airline reviews the reporting region's inspection data (3650s and 5650s), agrees or reviews with the reporting inspector.

Our office holds industry meetings and listening sessions. We try to level the playing field.

The FAA should look at the amount of a repair station's re-work (non-billable) as a measure of quality. We should also look at the percent of core group (permanent full time staff) to contract labor as well as the ratio of infrastructure staff to mechanics.

> There are great variances in PMI's abilities, skills, qualifications, quantity and location.
>
> One of the big challenges is keeping ASIs in so-called undesirable locations. Take xxx as an example; we get mostly new inspectors here. The ones from the local area plus a few who grow to like it and stay on. Most however want to go closer to home, or where the higher level jobs are to be found. After one year, a new person can transfer elsewhere. This means we are constantly training new people and our repair stations are forever seeing new inspectors. It's tough to maintain a consistent operation with such high turnover.
>
> There is one case where the PMI is 300 miles away from one of his major repair stations; they only see him every one to six months. To top it off, this repair station specializes in major structural repairs on transport aircraft; the PMI is a GA (General Aviation) inspector.
>
> Small vendors, who are also Part 145 certificated, experience lots of variances in PMIs and their territorial behavior.

One of the FSDOs visited, and in particular the PMI assigned to a major airframe repair station, does not accept partnership with his assigned repair station in any way, shape, nor form. Not only is partnership taboo in the eyes of this PMI, but he also asserts that this repair station (that he stated "is one of, if not the best") is generally not in compliance with the regulations. Further, this PMI has not and will not accept nor approve their maintenance error reporting and corrections program, part of their overall Maintenance Human Factors or MRM program. The repair station has an outstanding program. It is the only major 3rd Party repair station with a comprehensive program in operation based upon the industry standard Boeing Maintenance Error Decision Analysis (MEDA) program. The senior personnel from this repair station have received major industry awards for the excellent incorporation of the MRM program. The PMI has yet to accept and approve the program at this repair station.

This repair station also finds itself inundated with violation notices, letters of investigation, letters of finding, assessment of penalties, and a barrage of negative comments from their PMI. In addition, for whatever reason and from unknown sources, the Press has been provided with negative information concerning the repair station that should only be known, in any detail, by repair station senior management or the FAA.

The research team visiting this repair station was impressed with the site, the working conditions, processes, procedures, practices in place, and especially their MRM program. Their open door policy, which included, frank, honest, cooperative behavior on the part of the entire management team and workforce left a very positive impression. The same team visited the local FSDO and met with the station's PMI. We were equally impressed, though negatively, by this PMI's policeman based, enforcement only mentality, the negative comments about the organization and his strong opinions that their MRM program was only in place to evade serious rule and regulatory violations. This was the only site visit where the research team found such a negative environment or any serious deficiencies in the FAA Safety Inspection program.

This visit points out that even a system that is improving and running well overall can be negatively impacted by one individual. It was clear to the team that in this situation the FAA has a significant problem, that is well documented by a major repair station and all of their customers. This situation confirms comments that Regions, FSDOs, individual PMIs and ASIs can ignore programs developed in FAA headquarters, such as acceptance of Human Factors Error Reporting Systems

The situation also points out that while the autonomy of the Regions, Districts and individual FSDOs may be an effective structure through which to manage a large, complex organization, it can also have negatives. The FAA leadership should keep watch to ensure that this de-centralized system does not allow for the building of information exchange walls, and that individuals in the Regions, FSDOs, and individual PMIs/ASIs, do not operate contrary to overall agency policy.

3.8 THE FAA "SYSTEM" AND COMMUNICATIONS

- Many of the people, repair station and FAA alike, who talked with the research team seemed to feel that the problems and issues with the FAA are a result of the "system" itself. The primary source of problems point toward FAA Headquarters, not the operations in the field. The word dysfunctional was frequently used to describe operations at FAA Headquarters in Washington.

- There was a general consensus that too many upper level jobs within the FAA are filled by political appointees. These appointees often have little or no relative experience with the challenges and issues facing the Administration and/or the aviation industry. The middle managers and their professional staff appear stymied and restrained by those above them who have limited comprehension of what is needed and/or necessary to keep the system running effectively. There are persons of significant responsibility in both industry and the FAA who candidly state that they do their best to get the job done in spite of the FAA's leadership team. There is a good deal of concern that what is politically correct may not be the right thing to do. Those who were most candid felt that the senior staffers at DC headquarters spend so much time answering questions and responding to issues created by the inexperienced and politically motivated leadership, that they don't have time to do their own jobs.

Elements of these concerns were expressed in the April 1998 Guest Editorial for Aviation Maintenance Magazine entitled *Coercion, Intimidation and Delays.* The author opens with this qualification:

> "This is not about people, inspectors, nor administrators; the FAA has some of the finest individuals working in aviation today. They are highly dedicated professionals. This is not about them; this is about their system – a system that doesn't provide adequate tools, refuses responsibility and allows them to be crucified in the public media. In short, this is a broken system."

There is significant frustration within the industry over apparent inconsistencies in their system and overall communications. While usually not stated as succinctly as in this editorial, the concern and frustration coexist. The article continues:

> "But like other businesses today, the FAA is having trouble keeping the experienced folks out in the field. The experienced inspectors have advanced into management, which leaves a new breed of inspectors to represent the FAA. And like the emerging employees of today's businesses, this new generation needs guidance to compensate for experience." … "The guidance provided to inspectors, and often interpreted literally, is used to justify increased regulation of differing aspects of aviation. Interpretations vary between headquarters, regions, and often between inspectors, which results in extreme inconsistencies and significant disruption to the aviation industry."

The article goes on to discuss that the guidance provided by the Inspector's Handbook (8300-10) should not be used to go beyond ensuring that minimum standards are met. The Handbook does not permit the inspectors to disregard nor expand upon these minimums. The author goes on to state:

> "The FAA's responsibility is the enforcement of the minimum safety standard – not an arbitrary standard set by a guidance document."

A majority of those who participated in this research seldom blamed individuals within the FAA for their frustrations, however they did fault their "system." There is simply a great deal of frustration within the industry and FAA personnel in the field over the current state of the system resulting from what they view as a lack of quality leadership and the dysfunction it has created within headquarters operations.

The task of keeping an organization with over 45,000 employees well informed about current operations, issues and policies is difficult. The single area on which all individuals from all industry elements agreed was that FAA internal communications must improve. It is a topic of discussion at every forum in which the FAA participates, or at listening sessions their staff members attend. The need for more and open communication exists between headquarters and the field, region to region, FSDO to FSDO, and several points in between.

The FAA holds listening sessions at various industry meeting and seminars. A major topic of discussion at these sessions has to do with the variances in the interpretation of rules, regulations, and guidance materials. Interpretations vary from inspector to inspector, region to region, FSDO to FSDO, CMO to CMO and Region to Region. These differences can be significant. When known differences or conflicts of interpretation are brought up to the FAA at such sessions, they listen intently and usually agree to have the "appropriate people look into the situation." A major concern expressed by both FAA and 3rd Party repair station personnel, is that though those who can effect change listen and do nothing about what they hear, or simply hear but don't listen and then do nothing. Either change is so slow that it is not perceptible or changes are simply too difficult to make so none are made.

The following are several comments were made regarding the lack of any objective or formal means to rectify, remediate, resolve, or arbitrate disputes in interpretation. Many industry officials' feel there is no practical place to turn, and they simply do the best they can with the cards they are dealt. There seems to be a great deal of time spent within the aviation maintenance process dealing with differing views, opinions and interpretation of FAA rules, regulations and guidance materials. Perhaps if there were a revised, clearly defined communication and conflict resolution process, the system would operate with less confusion, conflict, and frustration.

3.8.1 Comments from Repair Station Personnel (Direct Quotes)

Apply new technology to improve maintenance performance. Go to those in the FAA who are most receptive and get it done.

The FAA should look at ISO 9000 (the Europeans use it big time) as a possible quality conformity standard. At least there could be one single system based upon one manual… the FAA should get behind ISO 9000 along with BF Goodrich, Boeing, General Electric, Pratt & Whitney, Rolls Royce, AirBus, Grumman, United Airlines and several others.

There is a revolving interpretation of policy and regulations. We have had three of four PMIs in the past four years or so. Each had a different modus operandi and interpretations of compliance. If you don't adjust, it can be very difficult. This is very confusing to the workforce and gives them a negative impression of the FAA.

Now that there is increased involvement between PMIs at repair station and customer airline's PMIs, at times there are two differing messages and interpretations.

The system seems to be polarized at two extreme ends… good and bad. It is almost like a marriage between the major 145s and the FAA, some good, some bad.

There are now three our four different interpretations of FAA regulations because they are, in fact, written by lawyers. In most other countries the regulators, those who possess industry knowledge, write the rules.

The FAA should do it better (right) and stop giving cart blanche Class 4 Certified Repair Station authorizations.

There needs to be a better tie-in between the NTSB and the FAA.

There should be monthly meetings required between the PMI and the repair station to discuss how goes it, problems, and plans for the operation.

We would like to be more involved and communicate with the FAA inspectors, but it seems to be becoming more one-way. Everyone is out of some sort of compliance with some aspect(s) of the regulation at some point in time.

There needs to be some sort of referee system that leads to mediation, and finally arbitration to resolve disputes between the repair stations and the FAA. Emotions and feelings must be considered, a strict and objective process would need to be developed. Headquarters (AVR-1) is the only objective alternative, but they remain in a "defend the FAA" posture.

There is no way to arbitrate. It takes an inordinate amount of time to override a PMI decision, if any one will do so. Regions do not want to arbitrate or override PMIs.

There should be some sort of rule/regulation interpretation database that can be accessed by both FAA inspectors and the repair stations. This could sure help with the differing interpretations of the same rules by different ASIs.

There are too many differences in interpretation. This can often boil down to plain stubbornness and can become confrontational.

There is too much regulation by Advisory Circular, Memos and Inspector's Handbook "8000" orders.

FAA bases interpretation at the region and with local 145/121 ASIs. This is the reason they are often so different. Add the third component, the manufacturers and their FAA certification inspectors and it really becomes confusing. There needs to be standardization on all sides and plenty of training to go along with it.

The FAA must implement a mediation and arbitration system. We could work with them to develop the process. There could be a database developed that would capture precedent and interpretation of standards. This would provide a means to use history, rather than going on a case by case or individual basis. With the OASIS system it should be a relatively simple task to do this and make it a process that all ASIs can easily use. There could be a simple Source Book or Handbook that is online with word and subject search.

Flight Standards appears to be fragmented and disjointed. Organizations are not coordinated; Regions and FSDOs do not use headquarters for interpretations.

Our local FAA is being very rigid due in part to the ValuJet environment, this stands in the way of progress. If interpretation is needed they should go to legal.

More and better surveillance causes some customers to go elsewhere. Are we causing companies to fail? Now, they are coming back to the stations they left to get better quality, sometimes it's a strange business.

The FAA is a reactionary organization, they are not proactive. It is an after the act, rather than before the fact group. The Fine Air DC-8 Miami accident is a classic; now there is a big push on pallet locks and Load Master qualifications. Next it will be fuel trucks, fueling and aircraft grounding.

There are too many industry culls that end up as ASIs. Doesn't the FAA check with former employers on their candidates before hiring them?

3.8.2 Comments from FAA Personnel

ATOS (Air Transportation Oversight System) is great for air carriers, not often used in 145s.

ATOS is a systematic inspection of air carriers. The ASIs, who become specialists, are trained. Lots of focus, detailed training, and open communications between FSDO specialists and CMOs. We are in constant communication.

OASIS (Operational and Supportability Implementation System) is a good system. There are some ASIs who still need training. Many of the "old hands," familiar with the old system, don't or won't use it. The newer personnel, who are for the most part at least somewhat computer literate, like and use the system. We have new desk top, networked computers in most FSDOs. Some of us don't use the OASIS laptops, but return to the office to complete their reports on the desktops.

The CSET (Certification Standardization Evaluation Team) system is very effective. This new program for air carrier certification is much better than how it was accomplished in the past.

Handbook bulletins without regulations to back them up don't help us. Don't tell us what we are responsible for in the field with no regulations to back us up. Who have they been talking to back there? - Not us!

Now we are regulated by handbook bulletins, where are the regulations we need?

Sexual harassment has top priority at legal. Violations are just not worth it. There is so much legality involved and they expect us to be legal folks. It took four years for one of our violations to go to actual collection of a fine, by then all of the folks involved were long gone. When you violate someone it simply takes too long to get action. Our objective is safety, if there is a problem – get it fixed!

Part of the problem is the supplemental airlines and the way they are certificated. It is a system that makes certification too easy, in fact it's a joke.

The legal people have a lot to say about what goes on in regulatory development. Legal people do not know a great deal about maintenance. Do the legal folks have too much control over regulations and regulatory policy?

The Regions, FSDOs and individual ASIs seldom, if ever, call headquarters (Flight Standards) any more for policy interpretation and direction.

Trickle down from HQ is severely watered down by the time it gets to the front line.

There are seven Regions out there, all producing policy. No wonder the troops in the field and the repair stations and air carriers are confused by the differing answers they receive for the same question or issue.

Upper management, no foolin', what do you want us [ASIs] to do? We need real guidance on what they want things to be, very unclear directions from AFS/AVR headquarters on what they want the PMIs and ASIs to do. Is there too much political pressure in headquarters? Headquarters has a lot of problems and the bureaucracy kills too much, there are simply too many hoops to go through to get anything done.

3.9 REGULATORY REVIEW, REVISION AND CHANGE

The entire aviation maintenance community, including FAA in the field and at Headquarters, are very frustrated with the process. All the information gathered on this issue can be summed up very simply, the system is broken, regulatory review, revision, change and implementation simply takes too long. Nothing ever happens. This has been expressed hundreds of ways, hundreds of times, by people from all facets of the aviation maintenance community, including those in the FAA who trust their anonymity will be protected. Those who will talk candidly on the subject don't know how to fix it, wish someone would take on the task, but hold little hope that it will change any time soon.

The United States' performance in aviation maintenance regulatory review and revision compared to the rest of the world appears to be quite grim. There is no one to be found in the industry or within the regulator that is happy about this issue. Transport Canada, have been active in the FAR Part 65/66 review process, and are a good example of how a revision to a regulation can happen in a timely fashion.

The 1997 GAO report included strong recommendations that FAR Parts 65/66 and 145 have the review and revision process concluded quickly, since then there has been no change, most people say it is worse than ever.

3.9.1 Comments Gathered on the Regulator Review Process (Direct Quotes)

The United States, supposedly a world leader in aviation, should be embarrassed with its' slow and archaic regulatory review and revision process. Review and revision of Parts 65/66 and 145 have been in process for about 9-10 years. Both rules are stalled in the process with no action toward implementation in process that would provide for implementation within the next two years.

The EEC, consisting of 11 European country's JAA developed and implemented both JAR Parts 66 and 147 in about 3½ years. These updated and harmonized rules, correspond to the US FAA Parts 65 and 147, are now recognized and followed by all EEC member states.

Transport Canada, the Canadian aviation regulatory body, reviewed, revised and produced a simplified version of their Aviation Maintenance Engineer (AME) rule (equivalent to the US A&P) in 2½ years. It was completed in house, with the input from industry, labor, and other interested parties. This significantly revised rule will become effective in June 1999.

FAA inspectors feel that Parts 66 and 145 will never come to rule. They feel it's certain that they will all be retired before it happens.

The industry has changed over the last 25 years; the FAA has also changed, Part 145 has not changed.

All of the FARs from 65 and up are poor, Part 25 is the best.

3.10 CONCLUSIONS

The aviation maintenance industry is staffed by people that know and understand their mission, and respect rules, regulations and regulators. There is no question that safety and continuous improvement is the primary objective. Repair station, airline, and the FAA personnel who oversee day-to-day operations are the backbone of our aviation maintenance safety system. They strive, regardless of what is going on above their levels of responsibility, to get the job done safely, efficiently and to make the operation better in every way they can.

The GAO 1997 report, *FAA Oversight of Repair Stations Needs Improvement*, registered concern over inspection frequency and quality, and the methodology of major repair station oversight and inspection performed by the FAA. Every indication leads to the conclusion that these issues have been addressed, and solved, and this part of the system is working well. This does not mean that there are not remaining issues and problems that need to be addressed. The critical problems and issues, however, have been rectified. The safety of aviation maintenance is under control, with high quality oversight and frequent inspection from the FAA.

It was clear during the fieldwork that repair station people felt free to be more candid and forthright with their comments, more willing to discuss specifics. FAA personnel, while concerned about areas that need improvement, were somewhat reluctant to spell out specifics, choosing most often to keep their comments to generalities. The reasons for the difference seemed to stem from the FAA's being constantly bombarded with criticism and rarely being given positive recognition for the job they have to do. There is also reluctance, for obvious reasons, on the part of the FAA folks in the field to be too critical of those up the line.

Relations between the Repair Stations and FAA are best at the field level. There is an atmosphere of mutual respect, each understanding the role of the other. It was reassuring to observe that the relationships between the PMIs, ASIs and the Repair Stations are, for the most part, positive. Given this, both the FAA in the field and the Repair Stations have difficulty with the FAA's systems, processes, communications from above, headquarters operations, and senior management (leadership). FAA staff in the trenches suggests that they keep things going well, in spite of what goes on at levels above the Regions.

The FAA is a very large organization that has monumental responsibilities. The organization is constantly under the microscope of public opinion, media scrutiny, congressional review and political pressure. They are under a constant barrage of often subjective, unsupported criticism from all quarters. The general public and the majority of the media have no idea, concept, or understanding of the complexity and difficulty of the FAA's task. It seems that when the system is running well they receive no credit, but when there is an accident or serious incident, they receive more blame than is deserved. Given all the above, the FAA has some serious and difficult problems to solve, issues to address, and processes that need improvement.

The aviation maintenance safety system works. It is meeting the objective of ensuring that work at major repair stations is in compliance with all rules, regulations, and procedures. The concern is the amount of unnecessary effort required, the frustrations in dealing with differing interpretations of the same subject, the lost productivity for both industry and the FAA, and the high costs this generates.

3.11 RECOMMENDATIONS

1. Review the organizational structure and operations of the FAA nine geographic regions. The comment that there are nine FAAs in operation out there is heard frequently. Each Regional Office is setting its' own policies and may differ widely their in interpretation of rules, regulations, and procedures. The regional organizational structure is in place to maintain sufficient management control over the system and keep the day to day operations on track. There is reason to believe, given some of the comments gathered during this project, that there is presently too much autonomy at the regional level, and that revisions to communication and management control procedures are required.

2. Aviation technical manuals, documentation and job task cards need to be reviewed and the need for industry standardization addressed. The FAA needs to challenge the aviation industry associations to meet this need by developing the necessary standards. If the industry cannot accomplish the task without rulemaking, the FAA should evaluate the situation and propose standardization rules as required. (Effective industry standards for Non-Destructive Testing, Guidelines for Maintenance Training, and Maintenance Human Factors Programs are examples of what can be accomplished.)

3. The worldwide safety improvements made through Human Factors in Aviation Maintenance and Inspection, and Error Management Programs needs to be recognized. The FAA should review the reasoning used by other international aviation regulatory agencies that caused them to include Maintenance Human Factors Programs in their operational rules. Objective consideration should be given to similar rulemaking in the US.

4. FAA Aviation Safety Inspector (Airworthiness) training needs to be reviewed for appropriate content, and effectiveness. The willingness of airlines and repair stations to participate in the field training and/or on-the-job training of PMIs and ASIs should be accepted and included in the FAA's program.

5. Provide online communications through FAA's outstanding web site, FAA.GOV, as to the status of all in process and proposed rulemaking. The information should contain current status, work currently in process, expected completion of such work, proposed release date of NPRM, if applicable, and/or the expected release date of rules. The same status information on pending Advisory Circulars and other procedural information should also be available on the web site.

6. Develop an open, easily accessed process for mediation and/or arbitration of disputes between PMIs/ ASIs and maintainers in the field. This should be an open, non-threatening, objective system where differing interpretation of rules and regulations can be quickly resolved. This could be accomplished with a simple referee review board, with follow on resolution steps up to and including binding arbitration. Enlist the participation of industry to help develop this process.

7. Conduct a formal, in depth, evaluation of current regulatory review, revision and change. There is sufficient input from every quarter that provides more than enough motivation and justification to move forward. After the review has been conducted and the results evaluated, necessary process revisions and changes should be made quickly. Though many in the FAA consider it to be world's leader, they should look to their counterparts in Canada and the EEC for guidance on how to improve the US system.

8. FAA leadership needs to spend more time meeting and working with personnel at the operational level of industry, and within their own ranks. Relying primarily on a small group of internal FAA senior management, technical representatives, and leaders of industry associations, and special interest groups, does not necessarily provide them with a clear view of what is going on within the industry. The FAA needs to work toward obtaining unfiltered, unbiased, information from the people who have to get the job done by doing it.

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CHAPTER 4
USE OF COMPUTER-BASED TRAINING FOR AIRCRAFT INSPECTION: MINIMIZING ERRORS AND STANDARDIZING THE INSPECTION PROCESS

Anand K. Gramopadhye, Brian J. Melloy, and George M. Nickles
Clemson University

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

4.1 EXECUTIVE SUMMARY

The Automated System of Self-Instruction for Specialized Training (ASSIST) is a computer-based training system for aircraft inspection. The product of this research and development is the software. ASSIST is published as two CD-ROMs and is available through the FAA website. This report describes the development process and the functionality of the software system.

4.2 INTRODUCTION

The Chapter is divided into three major sections. The first section provides the background information on the development of the Automated System of Self-Instruction for Specialized Training (ASSIST)—a computer based training tool for aircraft inspection. The section describes how previous years research efforts guided the development of the ASSIST program. The second section provides a brief description of the ASSIST program and the final section outlines the conclusions with recommendations for future research. The research was jointly pursued with two industry partners – Delta Air Lines, Atlanta, GA and Lockheed Martin Aircraft Center, Greenville, SC to ensure that it was relevant and addressed the needs of the aviation community.

4.3 BACKGROUND

The aircraft and inspection/maintenance system is a complex one with many interrelated human and machine components.[1,2] The linchpin of this system, however, is the human. Recognizing this, the Federal Aviation Administration (FAA), under the auspices of the National Plan for Civil Aviation Human Factors, has pursued human factors research. In the maintenance area this research had focused on the aviation maintenance technician (AMT). Since it is difficult to eliminate errors altogether, continuing emphasis must be placed on developing interventions to make inspection and maintenance more reliable and/or more error tolerant. Inspection is affected by a variety of entities. These entities include large international carriers, regional and commuter airlines, repair and maintenance facilities, as well as the fixed-based operators associated with general aviation. An effective inspection is seen as a necessary prerequisite to public safety, so both inspection and maintenance procedures are regulated by the U.S. Federal Government via the FAA. Investigators conducting this study found that, while adherence to inspection procedures and protocols is relatively easy to monitor, tracking the efficacy of these procedures is not.

4.3.1 The Aircraft Maintenance Process

The maintenance process begins when a team that includes representatives from the FAA, aircraft manufacturers, and start-up operators schedule the maintenance for a particular aircraft. This initial process is called the Maintenance Review Board (MRB). These schedules may be, and often are, later modified by individual carriers to suit their own scheduling requirements. These maintenance schedules are comprised of a variety of checks that must be conducted at various intervals. Such checks or inspections include flight line checks, overnight checks, and four different inspections of increasing thoroughness, the A, B, and C checks and the most thorough and most time-consuming, D check. In each of these inspections, the inspector checks both the routine and non-routine maintenance of the aircraft. If a defect is discovered during one of these inspections, the necessary repairs are scheduled. Following these inspections, maintenance is scheduled to 1) repair known problems, 2) replace items because the prescribed amount of air time, number of cycles, or calendar time has elapsed, 3) repair previously documented defects (e.g. reports logged by pilot and crew, line inspection, or items deferred from previous maintenance), and 4) perform the scheduled repairs (those scheduled by MRB).

In the context of an aging fleet, inspection takes an increasingly vital role. Scheduled repairs to an older fleet account for only 30% of all maintenance compared with the 60-80% in a newer fleet. This difference can be attributed to the increase in the number of age-related defects.[2,3] In such an environment the importance of inspection cannot be overemphasized. It is critical that these visual inspections be performed effectively, efficiently, and consistently over time. Moreover, 90% of all inspection in aircraft maintenance is visual in nature and is conducted by inspectors, thus inspector reliability is fundamental to an effective inspection. As in any system that is highly dependent on human performance, efforts made to reduce human errors by identifying human/system mismatches can have an impact on the overall effectiveness and the efficiency of the system. Given the backdrop of the inspection system, the objective of this particular study was to use training as an intervention strategy to reduce inspection errors.

4.3.2 Using Human Factors to Improve Aircraft Inspection Performance

An analysis of the inspector's role in inspection has pointed to a number of issues (e.g. inspector-oriented issues, environmental design issues, workplace design issues, etc.).[1,4] These issues have been continually addressed by the FAA.[3] Research conducted under this program has identified several ergonomic changes to both the system and to the inspector. System changes have included improved work control cards and crew resource management interventions.[5,6] Inspector-oriented interventions are 1) selection and 2) training. The current research concentrates on training and specifically the use of advanced technology for training as an improvement strategy.

4.3.3 The Need for Computer-based Inspection Training

Aircraft inspection and maintenance are an essential part of a safe, reliable air transportation system. Training has been identified as the primary intervention strategy in improving inspection performance. If training is to be successful, it is clear that we need to provide inspectors with training tools to help enhance their inspection skills.

Existing training for inspectors in the aircraft maintenance environment tends to be mostly on-the-job (OJT). Nevertheless, this may not be the best method of instruction.[7,8] For example, in OJT feedback may be infrequent, unmethodical, and/or delayed. Moreover, in certain instances feedback is economically prohibitive or infeasible due to the nature of the task. Thus, because the benefits of feedback in training have been well documented,[9] and for other reasons as well, alternatives to OJT are sought. Furthermore, training for improving visual inspection skills of aircraft inspectors is generally lacking at aircraft repair centers and aircraft maintenance facilities. However, the application of training knowledge to enhance visual inspection skills has been well documented in the manufacturing industry. Training has been shown to improve the performance of both novice and experienced.[9,10] Visual inspection skills can be taught effectively using representative photographic images showing a wide range of conditions with immediate feedback on the trainee's decision.[9] Using realistic photographic images as a training aid in controlled practice with feedback has also been shown to be superior to only OJT.[11]

Thus, off-line training/retraining with feedback has a role to play in aircraft inspection training. One of the most viable approaches for delivering training given the many constraints and requirements imposed by the aircraft maintenance environment is computer-based training. Computer-based training offers several advantages relative to traditional training approaches; for example, computer-based training is more efficient, facilitates standardization, and supports distance learning. With computer technology becoming cheaper, the future will bring an increased application of advanced technology in training. Over the past decade, instructional technologists have offered numerous technology based training devices with the promise of improved efficiency and effectiveness. These training devices are being applied to a variety of technical training applications. Examples of such technology include computer-based simulation, interactive videodiscs, and other derivatives of computer based applications. Compact disc read only memory (CD-ROM) and Digital Video Interactive (DVI) are two other technologies which will provide us with the "multi-media" training systems of the future. Many of these training delivery systems such as computer aided instruction, computer based multi-media training and intelligent tutoring systems are already being used today, thus ushering in a revolution in training.

In the domain of visual inspection, the earliest efforts to use computers for off-line inspection training were reported by Czaja and Drury.[12] They used keyboard characters to develop a computer simulation of a visual inspection task. Similar simulations have also been used by other researchers to study inspection performance in a laboratory setting. Since these early efforts, Latorella et al. and Gramopadhye, Drury and Sharit have used low fidelity inspection simulators using computer generated images to develop off-line inspection training programs for inspection tasks.[11,13] Similarly, Drury and Chi studied human performance using a high fidelity computer simulation of a printed circuit board inspection.[14] Another domain, which has seen the application of advanced technology, is that of inspection of x-rays for medical practice. In summary, most of the work in the application of advanced technology to inspection training has focused on developing low fidelity simulators for running controlled studies in a laboratory environment. Thus, research efforts need to be extended in order to take full advantage of today's computer technology. Moreover, advanced technology has found limited application for inspection training in the aircraft maintenance environment. Presently, most of the applications of computer technology to training have been restricted to the defense/aviation industry for complex diagnostic tasks. The message is clear: we need more examples of the application of advanced technology to training for inspection tasks that draw upon the principles of training which we already know will work. In this vein, this report describes a university and industry collaborative research effort to develop an off-line computer based inspection-training system for aircraft inspectors. The specific objective of this research was to develop an inspection training system that would help improve the visual search and decision making skills of aircraft inspectors. The computer based inspection training program entitled "Automated System of Self Instruction for Specialized Training" (ASSIST) was developed in cooperation with Lockheed Martin Aircraft Center and Delta Air Lines (Figure 4.1). A brief description of the system follows.

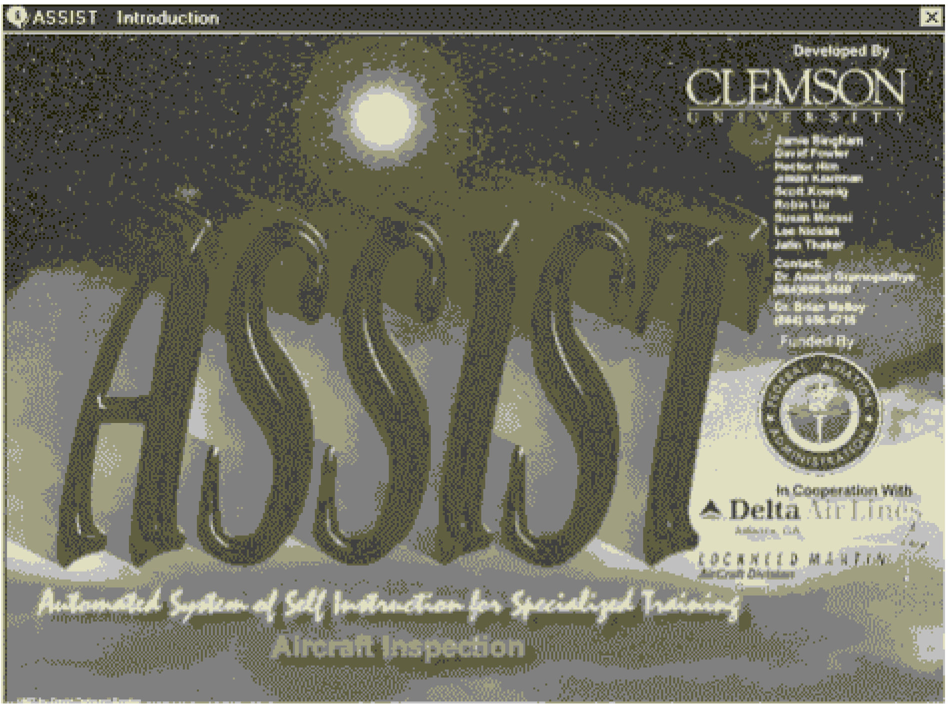

Figure 4.1 ASSIST Title Screen

4.3.4 Development of the ASSIST Program

The development of the ASSIST program followed the classic training program development methodology (Figure 4.2). It began with a thorough analysis of the requirements and needs (goals) of the training program. The task analysis, along with the trainee analysis, were used to compare the knowledge and skills required by the task with those possessed by the inspector to determine gaps which need to be addressed by the training program. Patrick has identified the training content, training methods and trainee as the important constituents of the training program.15 Drury includes the training delivery system as another component of the training program.16 Although a considerable amount has been written about designing training systems8,15 very little focuses directly on enhancement of visual inspection skills. Embrey states that for any training program to be effective, it should address the following three issues: attitude of the trainee at work, knowledge required to perform the job, and the specific skills required to perform the task.17 Specific training methods incorporated in development of the ASSIST program are described below.10,18

1. Pre-training: Pre-training provides the trainee with information concerning the objectives and scope of the training program. During pre-training, pretests can be used to measure (a) the level at which trainees are entering the program and (b) cognitive or perceptual abilities that can later be used to gauge training performance/progress. Advanced organizers or overviews, which are designed to provide the trainee with the basics needed to start the training program, have been found to be useful. The elaboration theory of instruction proposes that training should be imparted in a top-down manner wherein a general level is taught first before proceeding to specifics. Overviews can fulfill this objective by giving the trainee an introduction to the training program and facilitating assimilation of new material.

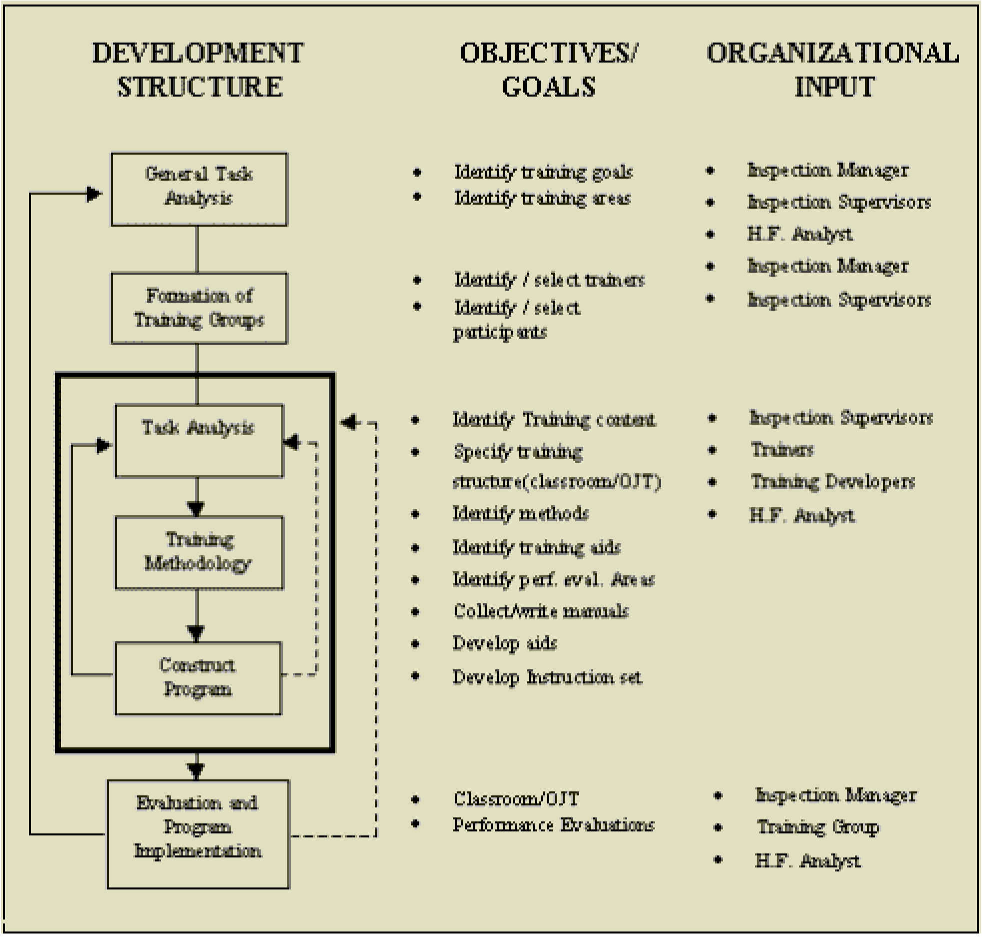

Figure 4.2 Model for Training Program Development in Commercial Aviation

2. Feedback: A trainee needs rapid, accurate feedback in order to know whether a defect was classified correctly or a search pattern was effective. Some attempt of performing the task followed by feedback with knowledge of results provides a universal method of improving task performance.9 This applies to learning facts, concepts, procedures, problem solving, cognitive strategies and motor skills. The training program should start with immediate feedback, which should be gradually delayed until the "operational level" is reached. Providing regular feedback beyond the training session will help to keep the inspector calibrated. Gramopadhye, Drury and Prabhu classify feedback as performance and process feedback.18 Performance feedback on inspection typically consists of information on search times, search errors and decision errors. Process feedback, on the other hand, informs the trainee about the search process, such as areas missed. Another type of feedback called "cognitive feedback" has emerged from the area of social judgement theory. Cognitive feedback is the information provided to the trainee of some measure of the output of his or her cognitive processes. For inspection tasks, process feedback is the same as cognitive feedback.

3. Active Training: In order to keep the trainee involved and to aid in internalizing the material, an active approach is preferred. In active training, the trainee makes an active response after each piece of new material is presented, e.g., identifying a fault type. Czaja and Drury used an active training approach and demonstrated its effectiveness for a complex inspection task.12

4. Progressive Parts Training: Salvendy and Seymour successfully applied progressive part training methodology to training industrial skills.19 In the progressive parts methodology, parts of the job are taught to criterion and then successively larger sequences of parts are taught. For example, if a task consists of four elements E1, E2, E3 and E4, then the following would follow:

- Train E1, E2, E3 and E4 separately to criterion
- Train E1 and E2; E3 and E4 to criterion

- Train E1, E2 and E3 to criterion and E2, E3 and E4 to criterion
- Train the entire task to criterion

This method allows the trainee to understand each element separately as well as the links between the various elements thus representing a higher level of skill. On the other hand, reviews of literature reveal that part task training is not always superior. The choice of whether training should be part or whole task training depends on "cognitive resources" imposed by task elements and the "level of interaction" between individual task elements.8 Thus, there could be situations in which one type of task training is more appropriate than the other. Naylor and Briggs have postulated that for tasks of relatively high organization or complexity, whole task training should be more efficient than part task training methods.20

5. Schema Training: The trainee must be able to generalize the training to new experiences and situations. For example, it is impossible to train the inspector on every site and extent of corrosion in an airframe so that the inspector is able to detect and classify corrosion wherever it occurs. Thus, the inspector will need to develop a "schema" which will allow a correct response to be made in novel situations. The key to the development of schema is to expose the trainee to controlled variability in training.

6. Feedforward Training: It is often necessary to cue the trainee as to what should be perceived. When a novice inspector tries to find defects in an airframe, the indications may not be obvious. The trainee must know what to look for and where to look. Specific techniques within cueing include match-to-sample and delayed match-to-sample. Feedforward information can take different forms such as physical guidance, demonstrations, and verbal guidance. Feedforward should provide the trainee with clear and unambiguous information, which can be translated into improved performance.

The ASSIST training program was based on a detailed taxonomy of errors and developed from the failure modes of each task in aircraft inspection. This taxonomy,7 based on the failure modes and effects analysis (FMEA) approach, was developed due to the realization that a pro-active approach to error control is necessary to identify potential errors. Table 4.1 shows only a portion of the taxonomy for the decision-making component of the inspection task. The error taxonomy provided the analysts a systematic framework to suggest appropriate content for the ASSIST training program. The ASSIST training program specifically focused on the search and decision making components of the inspection task. These have also been shown to be determinants of inspection performance21,22 and the two most critical tasks in aircraft inspection.2,3,23 As an example, Table 4.2 shows how errors (see column 5) (identified from the error taxonomy – Table 4.1) for each subtask of the decision-making task (see column 1) were addressed by the specific modules of the ASSIST training program (see columns 2, 3, and 4). Column 2 specifies the training content, column 3 outlines the method used for training and column 4 specifies the specific training module within ASSIST. A detailed description of the ASSIST program follows.

Table 4.1 Error Taxonomy for Decision Making in Aircraft Inspection

TASK	ERRORS	OUTCOME
4. DECISION		
4.1 Interpret indication.	• Classify as wrong defect type.	All indications located are correctly classified, correctly labeled as fault or no fault, and actions correctly planned for each indication.
4.2 Access comparison standard.	• Choose wrong comparison standards. • Comparison standard not available.	

	• Comparison standard not correct. • Comparison incomplete. • Does not use comparison standard.	
4.3 Decide on if fault.	• Type I error, false alarm. • Type II error, missed fault.	
4.4 Decide on action	• Choose wrong action. • Second opinion if not needed. • No second opinion if needed. • Call for buy-back when not required. • Fail to call for required buy-back.	
4.5 Remember decision/ action	• Forget decision/action. • Fail to record decision/action.	

Table 4.2 Examples of Errors Addressed in the ASSIST Program

TASK	CONTENT OF ASSIST	METHOD	PROGRAM MODULE	ERROR ADDRESSED FROM TASK ANALYSIS
4 DECISION				
4.1 Interpret indication	Present examples of defects and identify in simulator	Active and Feedback	General Module, Simulator	• Classify as wrong fault type
4.2 Access comparison standard	Use simulator to access information on defects, locations, and action	Active and Feedback	General Module, Simulator	• Choose wrong comparison standards • Comparison standard not available • Comparison standard not correct • Comparison incomplete • Does not use comparison standard
4.3 Decide on if it's a fault	Use simulator with real defects and feedback	Progressive parts, Active, and Feedback	Simulator	• Type I error, false alarm • Type II error, missed fault
4.4 Decide on action	Complete NR card with Feedback in correct way to fill out card	Active and Feedback	Simulator	• Choose wrong action
4.5 Remember decision/ action	Enter multiple defects and complete NR card with feedback	Active and Feedback	Simulator	• Forget decision/action • Fail to record decision/action

4.4 AUTOMATED SYSTEM OF SELF-INSTRUCTION FOR SPECIALIZED TRAINING (ASSIST)

4.4.1 System Specifications

ASSIST was developed using Visual Basic and Microsoft Access. The development work was conducted on a Pentium 120 MHz platform with a 17" high resolution monitor (0.28 mm dot pitch, non-interlaced), 32 MB RAM, 2 MB video RAM, ATI Mach 32 VLB advanced graphics accelerator card, 2GB Hard Drive, 36X-speed CD-ROM drive using a Reveal multimedia kit. The training program uses text, graphics, animation and audio. The inputs to the system are entered through a keyboard and a two-button mouse.

4.4.2 System Structure

The overall structure of ASSIST is shown in Figure 4.3. ASSIST consists of three major modules: (1) General Inspection module, (2) Inspection Simulation Training module, and (3) Instructor's Utilities module. All system users interact through a user-friendly interface. The user interface capitalizes on graphical user interface technologies and human factors research on information presentation (e.g. color, formatting, layout, etc.), ease of use and information utilization.

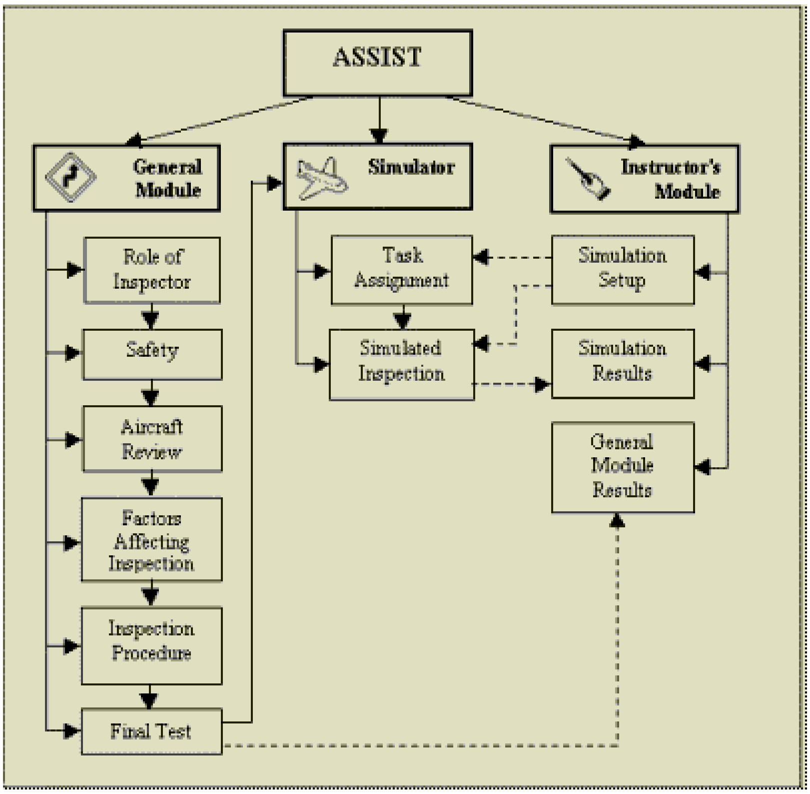

Figure 4.3 Components of the ASSIST Aircraft Inspector Training Program

4.4.3 General Module

The objective of the general module is to provide the inspectors with a basic overview on the following topics: (1) role of the inspector, (2) safety, (3) types of aircraft, (4) factors affecting inspection performance, and (5) inspection procedure. The module incorporates multimedia (sound, graphic, text, pictures and video) with interaction opportunities between the user and the computer. Figure 4.4 shows a typical screen of the general inspection module.

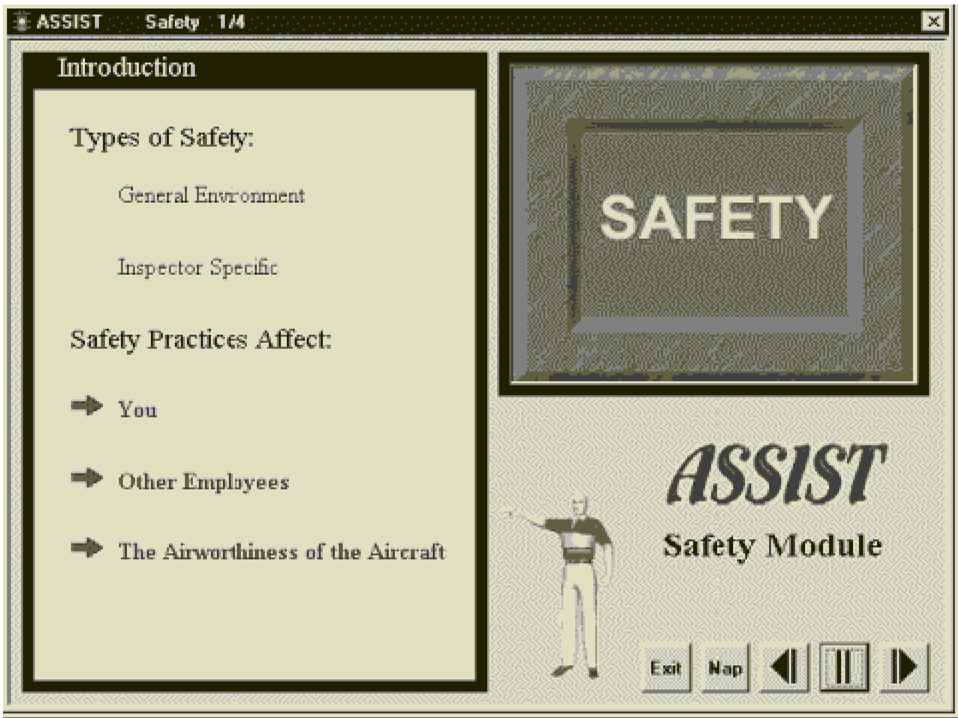

Figure 4.4 The Safety Topic of the General Module

4.4.4 Inspection Simulation Training Module

This module of the training program provides inspection training on a simulated aircraft inspection task (Aft Cargo Bin inspection of a Lockheed Martin L-1011) (Figure 4.5.). By manipulating the various task complexity factors the inspector can simulate different inspection scenarios. The simulation module uses actual photographs of the airframe structure with computer-generated defects.

Introduction The introduction provides the trainee with an overview of the various facets of the program, the work card for the inspection assignment and a graphical representation of various faults. The section introduces the trainee to the search and decision making aspects of the visual inspection task.

Testing The testing module is designed to operate in two separate modes: with and without feedback. The non-feedback mode simulates the actual visual inspection task as it would take place in the hangar. In either mode, the inspector first locates the defect and indicates this by clicking on the fault. Subsequently, the inspector classifies the defect. In the feedback mode, the inspector is provided with feedback on his/her performance on the search and decision making components of the inspection task. The trainee is also provided with end-of-session performance feedback. The program also features paced and unpaced modes. Paced mode allows the inspection to continue for only a specified period of time, while unpaced mode allows the inspection task to be unbounded by time.

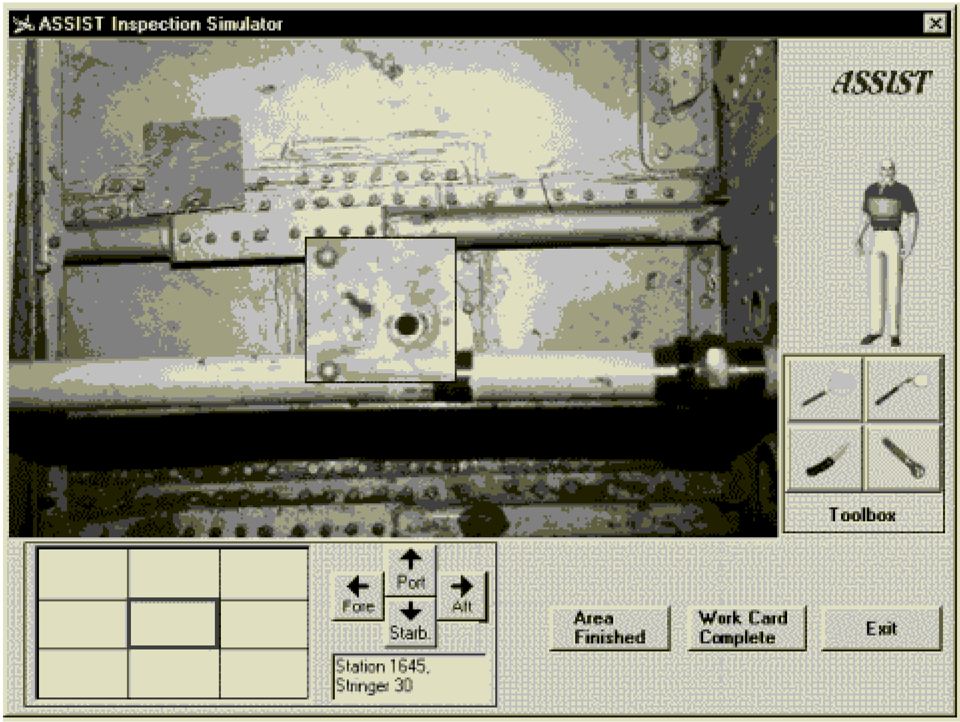

Figure 4.5 The Inspection Simulator Showing the Use of the Magnifying Glass

4.4.5 Instructor's Utilities Module

This module allows the supervisor/instructor to access the results database, the image database and the inspection parameter modules (Figure 4.6). The module is designed as a separate stand-alone tool that is linked to the other modules of the system. The results database allows the instructors to review the performance of a trainee who has taken several training and/or testing sessions. Performance data is stored on an individual image basis and summarized over the entire session so that results can be retrieved at either level. The utility allows the instructor to print or save the results to a file. The objective of the image database module is to provide the instructor with a utility wherein a specific image along with its associated information can be viewed on the computer screen. By manipulating the inspection parameters the instructor can create different inspection scenarios. The inspection parameter module allows the instructor to change the probability of defects, defect mix, the complexity of the inspection task, the information provided in the work card (thereby varying the feedforward information provided), whether the inspection will work in feedback mode or non-feedback mode, and whether the inspection task is paced or unpaced.

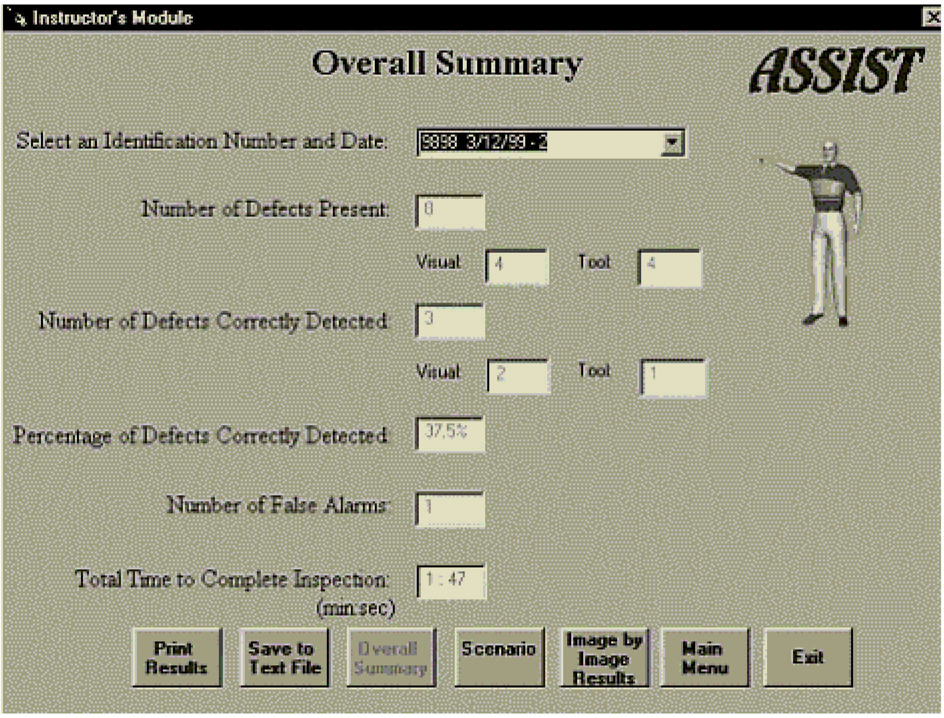

Figure 4.6 The Simulator Results Section of the Instructor's Module

4.4.6 Inspection Training Session

The training program was designed to use the general principles listed earlier in the context of this particular inspection job as derived by the task analysis. A major prerequisite was that it be a progressive part training scheme which enabled the inspectors to build their repertoire of knowledge and skills in an orderly manner. A typical training session proceeds as follows:

1. Initial Overview: Initially the subjects use the introduction module, wherein they are introduced to the navigation map, and are familiarized with the operational aspects of the computer program.

2. General Module Training: In the general module the subjects are provided information on the following five topics relevant to an inspector: role of the inspector, safety, aircraft review, factors affecting inspection, and inspection procedures. Using the navigation map, the subjects can either directly go to a particular topic or sub-topic, or follow the default path through the topics. At the end of each topic, a brief quiz is administered to review the subject's understanding of the material. The subjects are provided feedback and correct answers supplied. On completion of the topics in the general module, the subjects take the final test. The final test consists of questions selected from a database and covers material from each topic within the general module.

3. Simulation Module: In the simulation module, subjects are initially introduced to the workings of the simulator. Following this step, the subjects are presented with a work card containing the instructions for the inspection assignment (Figure 4.7). Next, the subjects are provided with information on defect standards (Figure 4.8). This includes images of the defects, descriptions, likely locations for particular defects, and possible indicators. Following this step the subjects conduct inspection using representative images of airframe structures wherein they have to first search for the defect and later classify the defect as one necessitating maintenance action or not. The simulator allows the use of various inspection tools: mirror, flashlight, scraping knife, and magnifying glass to assist the subject in performing inspection (Figure 4.5). If a defect is found, subjects complete a discrepancy report. On completion of the task, subjects are provided with feedback on the overall performance. Feedback is provided on the subject's search and decision making performance (time to complete inspection, defect detection, defect classification performance, etc). The simulator can be operated in various modes (e.g., with or without feedback (Figure 4.9), paced or unpaced) and also allows the instructor to set various inspection parameters (e.g., mix of defects, defect

probability, workcard instructions) thereby facilitating the creation f different inspection scenarios.

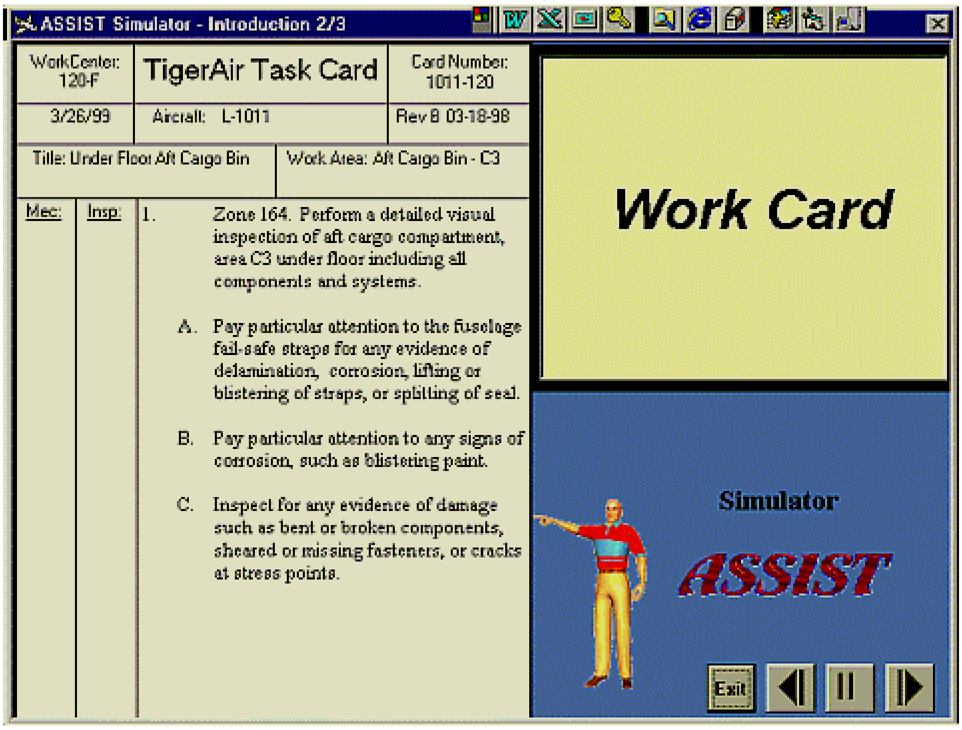

Figure 4.7 Work Card Assignment in the Simulation Module

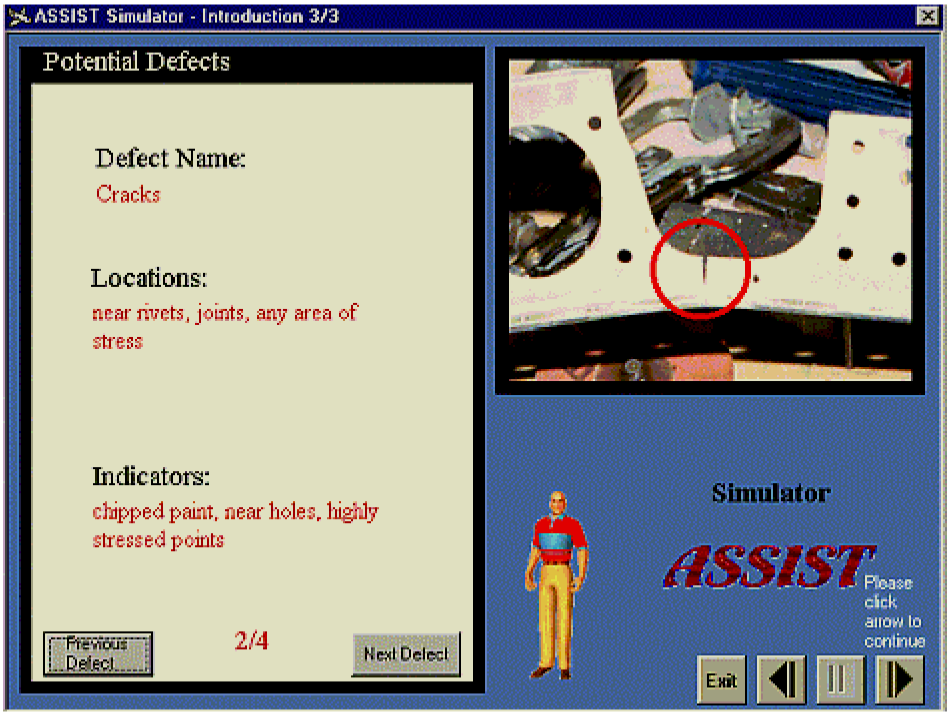

Figure 4.8 Defect Standards of Defects in the Simulated Inspection

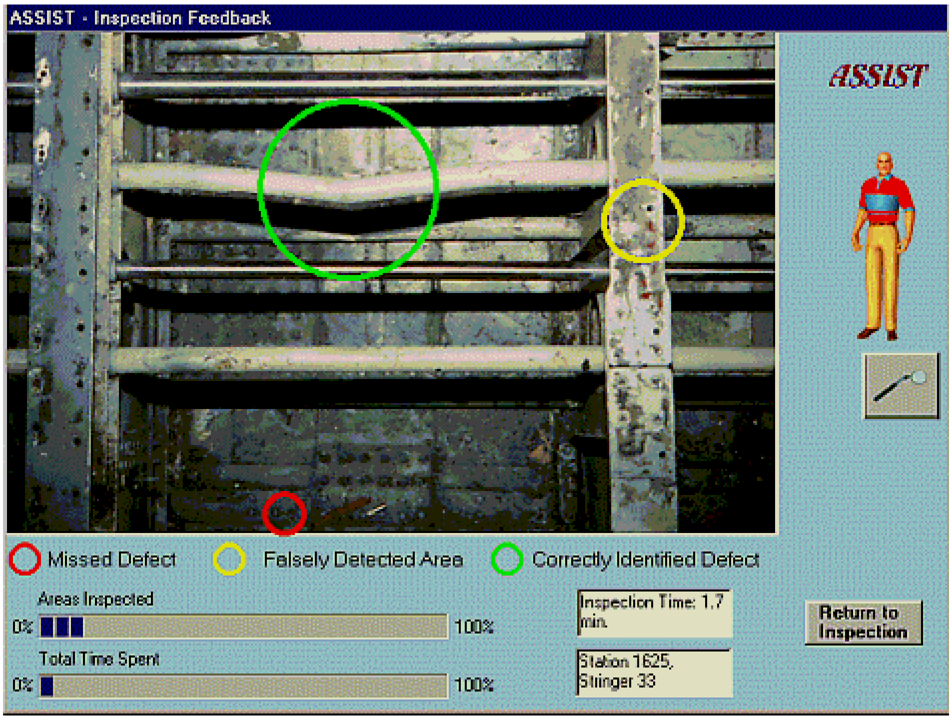

Figure 4.9 Screen by Screen Feedback in the Simulator When in Feedback Mode

4.5 CONCLUSIONS AND EXTENSIONS

The high degree of control that ASSIST affords will create the opportunity to systematize the inspection training process. In addition, there are several other inherent advantages that will serve to the alleviate the problems characteristic of OJT:

Completeness. Inspectors can be exposed to a wide variety of defects, with varying degrees of severity, at different locations, through the use of a library of defect images. Inspectors can also be trained on less frequently occurring critical defects.

Adaptability. ASSIST can be modified to meet the needs of individual inspectors. Batch files of images can be created to train inspectors on particular aspects of the inspection task with which they have the greatest difficulty. Thus, the program can be tailored to accommodate individual differences in inspection abilities.

Efficiency. Since the training will be more intensive, the trainees will be able to become more skilled within a shorter period of time.

Integration. The training system will integrate different training methods (e.g., feedback training, feed-forward training, and active training) into a single comprehensive training program.

Certification. ASSIST can be used as part of the certification process. Since the record keeping process can be automated, instructors can more easily monitor and track an individual's performance, initially for training and later for retraining.

Instruction. ASSIST could be used by instructors in FAA certified A&P schools for training. In this manner, for example, aircraft maintenance technicians could gain exposure to defects on wide-bodied aircraft that they might not have otherwise.

The report has described research in the area of aviation maintenance and inspection currently underway at Clemson University. Through the development and systematic application of human factors techniques, the research aims at improving the effectiveness and efficiency of aircraft visual inspection. The results of the research effort have been made available to the aviation maintenance community as deliverable products in the form of usable CD-ROMs. It is anticipated that the use of these products would lead to improved airworthiness of the U. S. domestic aircraft fleet. Subsequent phases of this research will evaluate the utility of ASSIST in an operational setting with aircraft inspectors. Finally, this research has future implications as well, the human performance models developed as part of the FY 97 activities could potentially be used in conjunction with ASSIST for a wide range of controlled studies. This would involve the evaluation of the effect of various task (e.g., pacing), subject (e.g., individual differences, fatigue) and environmental factors (e.g., noise and work interruptions) on aircraft inspection performance. Results forthcoming from this research would lead to the identification of specific interventions to enhance inspector performance and ultimately aviation safety.

4.6 ACKNOWLEDGMENTS

This research was funded by a grant to the Department of Industrial Engineering, Clemson University from the Office of Aviation Medicine, Federal Aviation Administration (Program Manager: Jean Watson).

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CHAPTER 5
AN ASSESSMENT OF INDUSTRY USE OF FAA HUMAN FACTORS RESEARCH FROM 1988 THROUGH 1998

William B. Johnson, Ph.D.
Galaxy Scientific Corporation

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

5.1 EXECUTIVE SUMMARY

Eleven years ago the Federal Aviation Administration (FAA) Office of Aviation Medicine embarked on a research and development program dedicated to human factors in aviation maintenance and inspection. Since 1988 FAA has invested significant funding for maintenance and inspection-related human factors research. The Office of Aviation Medicine has nearly lost count of the number of software products, technical publications, and public presentations delivered by the research team. With over 400 technical reports (see www.hfskyway.com) and over 15 significant software deliverables, it is time to assess the usefulness of the outcomes of the research. This report looks beyond the long list of research outcomes to assess the impact of the research in industry.

In cooperation with the US Air Transport Association (ATA), the Association of Asia Pacific Airlines (AAPA), and the Civil Aeronautics Authority (CAA) of the UK, the FAA researchers circulated a questionnaire regarding human factors in maintenance and inspection (See Appendix 1). The international industry sample of 122 respondents represented all aspects of the aviation maintenance industry. The results, described herein, show a very active interest in maintenance human factors. Most participants were familiar with the FAA research program and used many of the research by-products. The Research and Development (R&D) program received overall high marks.

5.2 GOALS OF THE ASSESSMENT

The primary goal of the assessment is to determine the extent to which the research program has influenced human factors in aviation maintenance environments. The survey attempts to assess the current status of human factors in airline maintenance environments. The survey also attempts to achieve a backward glance at the evolution of maintenance human factors, within the industry, since 1988. The assessment also has the goal of identifying the general category and specific projects perceived to be most useful. Finally, the assessment attempts to identify perceived needs that can be met by the FAA R&D program in the future.

This report will show that the assessment did accomplish these goals. In fact, many qualitative measures indicate that the FAA Office of Aviation Medicine research program is the very nucleus of human factors information for the aviation maintenance industry.

5.2.1 Assessment Instrument

A straightforward questionnaire was used to gather information from the industry. This method was selected for many reasons. First, the questionnaire would ensure standardization among respondents and that the same questions were asked of each participant. The written questionnaire also ensured that respondents would be neither influenced nor intimidated by the researcher. Due to the global nature of the aviation industry, the questionnaire format was the most economically feasible as well.

Nearly all the questions offered a five point Likert-type scale, ranging from "Strongly Disagree" (1) to "Strongly Agree" (5). Therefore, most of the numbers reported below will be between 1.0 and 5.0. Blank answers were not counted in the scale. Sections 3 through 6 of the questionnaire have an area for comments. These comments are selectively discussed in the report and included as Appendix 2.

The questionnaire is divided into five distinct sections as follows:

I. General Demographic Information

II. Current Status of Maintenance Human Factors Programs in Your Organization

III. Your Knowledge of FAA Human Factors R&D Products

IV. The Value of FAA Human Factors Research Products

V. Perceived Requirements for Aviation Maintenance Human Factors Products

5.3 DEMOGRAPHIC DATA

The demographic section has the traditional questions associated with name (optional), title, organization type, and years of experience in aviation and in human factors.

5.3.1 Geographical Distribution

Figure 5.1 shows the geographical profile of the 122 respondents. Four continents and 16 countries were represented in the sample. The United Kingdom has the highest number of respondents due to the fact that the Civil Aviation Authority was very assertive in distributing questionnaires during the 12th FAA/CAA/Transport Canada Symposium on Human Factors in Maintenance and Inspection.

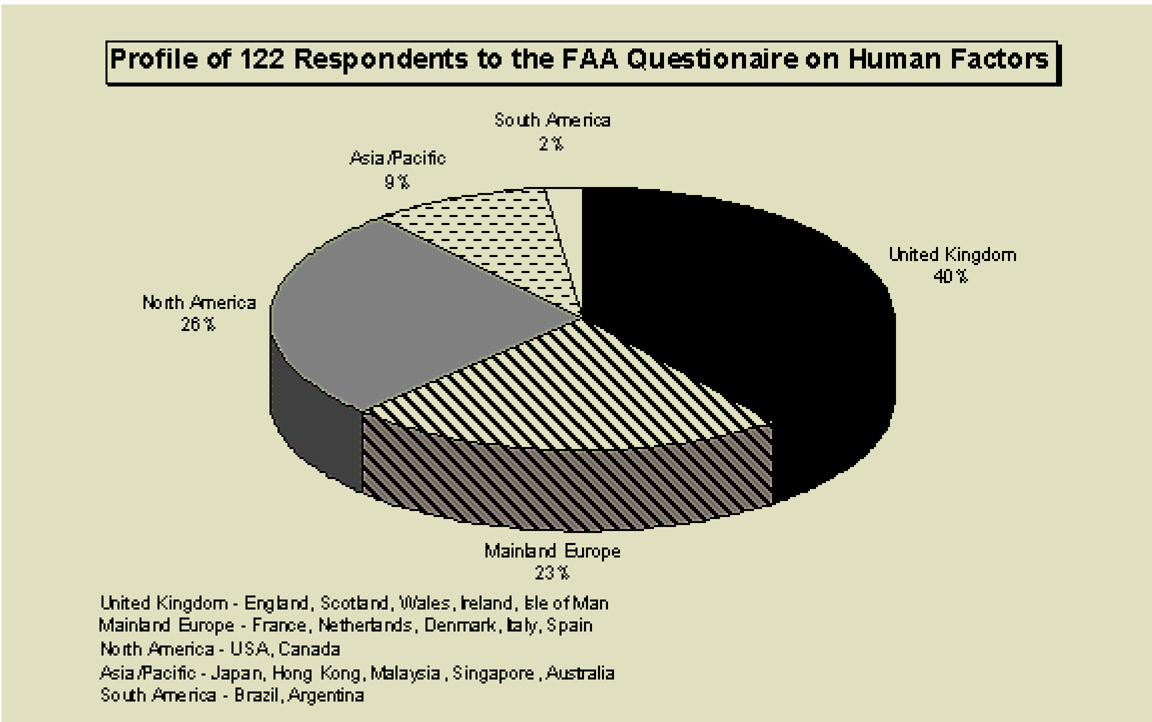

Figure 5.1 Geographical Profile of the Respondents

5.3.2 Industry Segments Represented

Figure 5.2 shows that most segments of the aviation industry are represented in the respondent group. Expectedly, airlines represent the largest portion of the respondents, at 48%. This is appropriate since the research program focused primarily on airline maintenance.

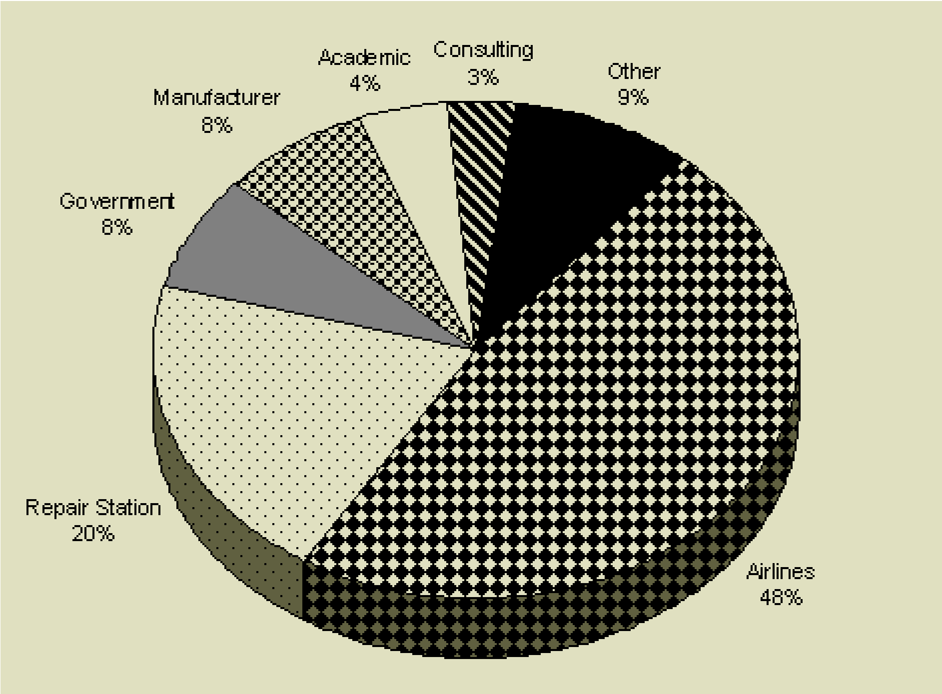

Figure 5.2 Industry Segments in Sample

5.3.3 Respondent Experience

The survey respondents have extensive experience in the aviation maintenance industry. Average experience is 25 years (SD= 11.58), with a median of 27 years. This high experience level is attributable to the fact that airline representatives to the ATA, AAPA, or at international conferences are likely to have reasonably high rank within the organization. The high experience level of respondents should help to ensure that answers are based on a very good knowledge of past, current, and planned maintenance human factors activities within the organization.

Average human factors experience was relatively low at 4 years. The majority of the respondents reported 1 to 8 years of human factors experience. Again, with the emerging interest in maintenance human factors this is an expected range. Figure 5.3 shows distributions of experience by aviation and human factors experience. The groups depicted by the demographic data are especially qualified to represent the industry consensus on human factors in maintenance.

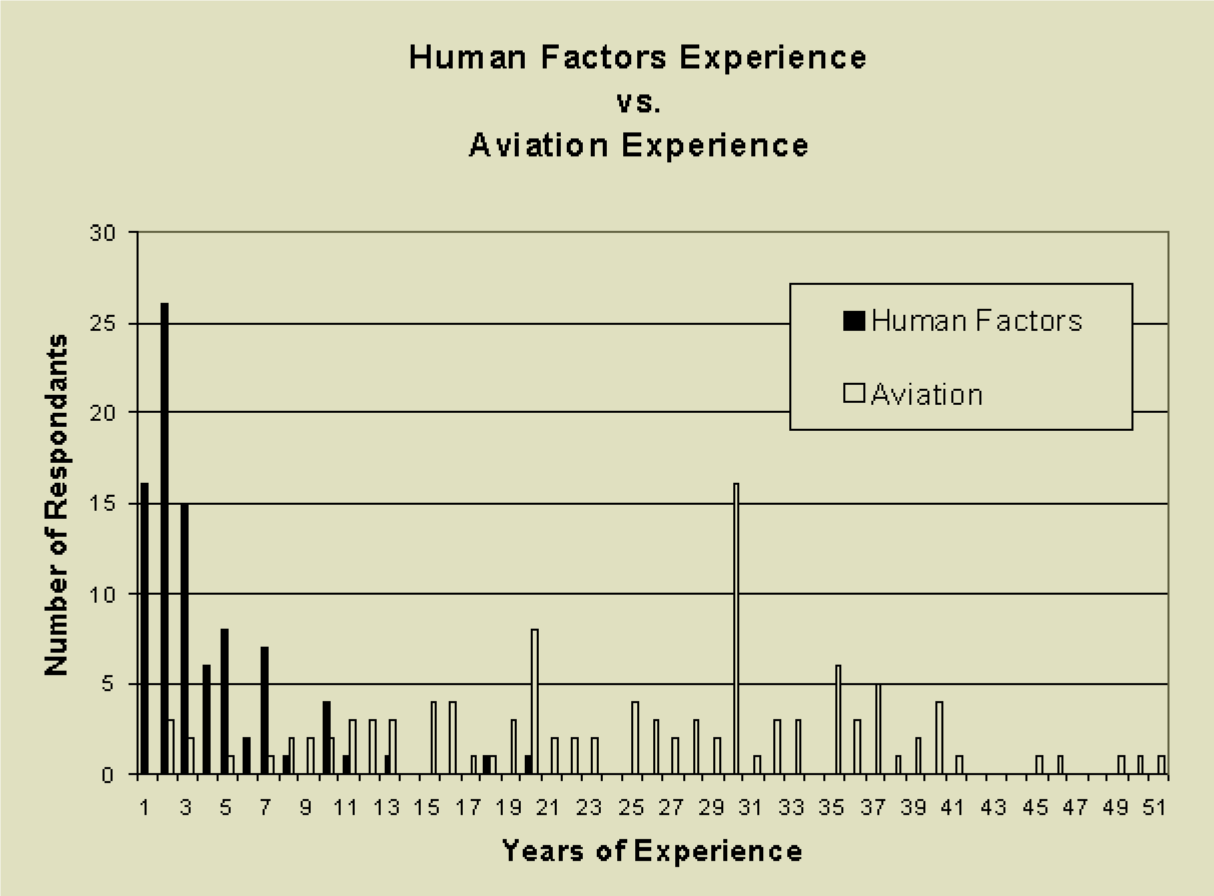

Figure 5.3 Graphic Depiction of Human Factors and Aviation Experience

5.4 CURRENT STATUS OF MAINTENANCE HUMAN FACTORS PROGRAMS IN RESPONDENTS' ORGANIZATION

This section establishes the existence and plans for maintenance and inspection human factors programs. The questionnaire was designed to ask not only whether the organization has a human factors program, but also what specific activities and products they are using. Use of human factors products is, most likely, the best indication of an active human factors program.

Average response to activity of a human factors program was 3.6/5.0 (SD=1.3). The industry segment with the highest activity is the airlines, as shown in Figure 5.4. More organizations are planning a human factors program with the average response at 4.0. The responses regarding maintenance and inspection human factors training programs are identical to the responses about a general human factors program. There is a high level of human factors interest, receiving a rating of 4.0/5.0 (SD=1.0).

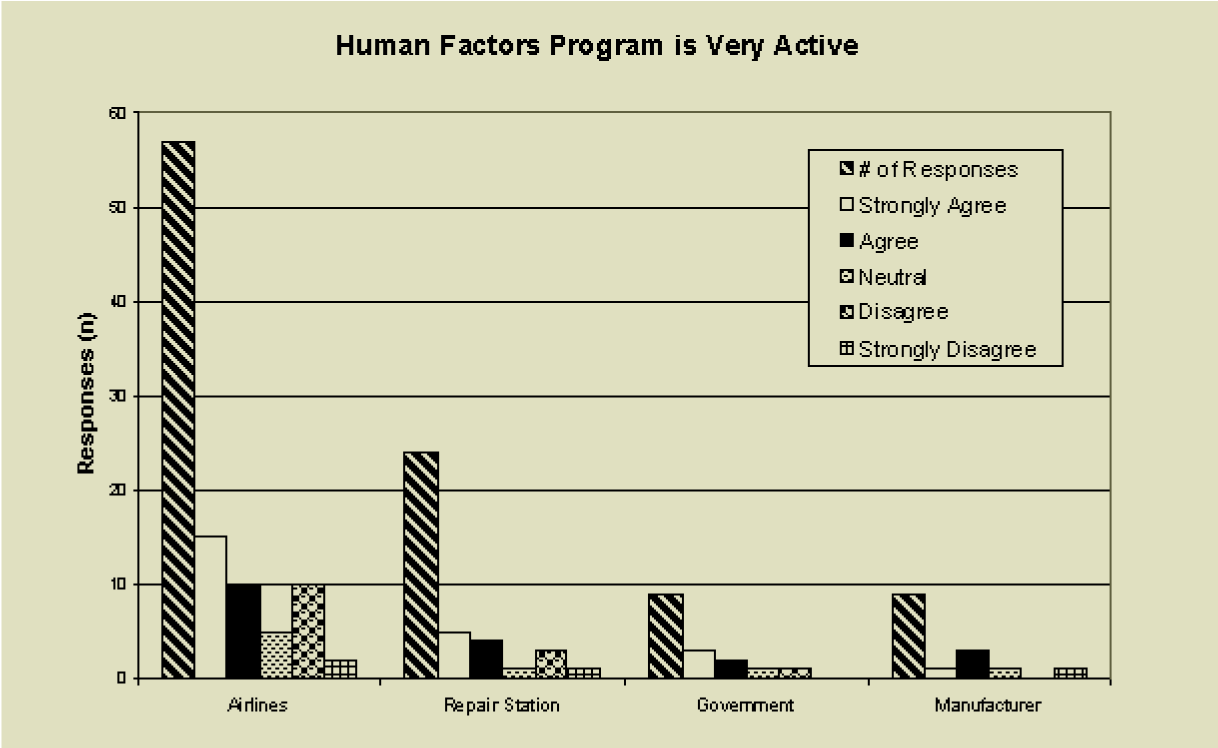

Figure 5.4 Industry Segments Reporting Human Factors Programs

Questions 3.5 through 3.13 were Yes-No type. Table 5.1 summarizes that data.

Table 5.1 Status of Maintenance Human Factors Programs in Respondents' Organization

Activity	Yes (%)	No (%)	Not Sure (%)	No. of Respondents
We use the "Dirty Dozen Posters" somewhere in our organization	46	44	10	119
We use information from the FAA Human Factors Aviation Research:				
Conferences	72	23	5	118
CD-ROMs	65	32	3	103
Reports	53	38	9	105
Website	49	48	3	112
We have sent people to specialized human factors courses	67	30	3	120
We have hired consultants to deliver human factors courses	27	67	5	120
We have a formal human factors error reporting system	34	59	7	92
We are planning a formal human factors error reporting system	63	19	18	69
We have a formal discipline system that acknowledges the importance of error reporting	50	42	8	111
We use data from our error reporting system	43	53	4	104
We have conducted a human factors audit of our maintenance organization	19	71	10	114
We plan to conduct a human factors audit	37	33	30	105

Perhaps the most interesting responses on Table 5.1 are the high responses to use of FAA information. Assuming the sample is representative of the industry at large, over 50% of the industry is using the FAA materials. Also a very high percentage of the respondents, 67%, have sent personnel to Human Factors training. Active and planned error reporting systems also received high response percentages.

5.5 RESPONDENTS' KNOWLEDGE OF FAA HUMAN FACTORS R&D PRODUCTS

This section of the questionnaire is designed as a means to determine if the respondents are using the by-products of the FAA Human Factors in Aviation Maintenance and Inspection Research Program.

Respondents generally agree that the FAA reports on maintenance human factors are useful, rating the question 3.8/5.0 (SD= .9). Satisfaction with the reports is generally shared by all segments of the respondents. Figure 5.5 depicts satisfaction level based on industry segment.

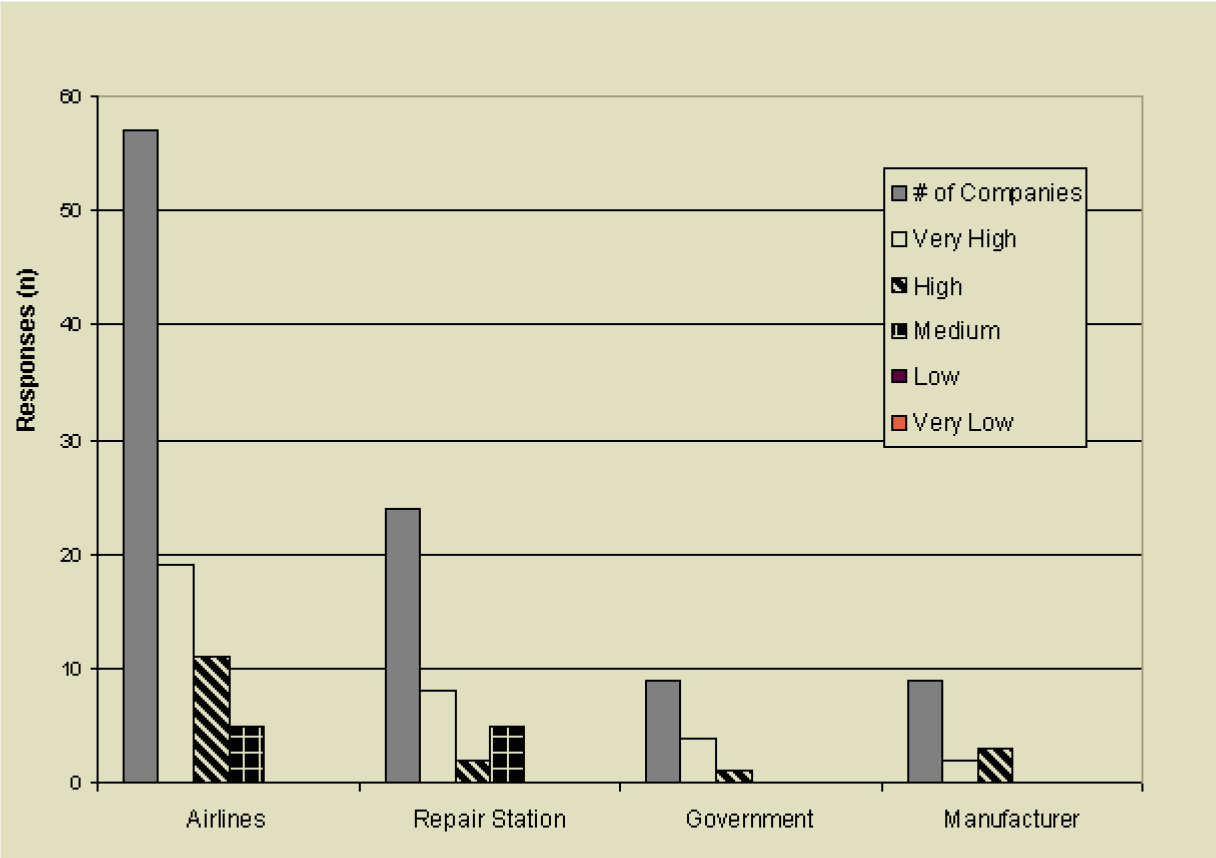

Figure 5.5 Satisfaction Level by Industry Segment

Table 5.2 shows the responses to the YES-NO format questions numbered 4.4 through 4.7.

Table 5.2 Knowledge of the FAA Human Factors R&D Products				
Activity	**Yes (%)**	**No (%)**	**Not Sure (%)**	**No. of Respondents**
I have received at least 3 CD-ROMs from the FAA concerning Aviation Maintenance Human Factors	44	53	3	120
My organization has participated in at least one FAA Human Factors research activity	28	59	13	117

Have you implemented FAA Aviation Maintenance Human Factors research products/interventions?	22	62	16	116

Representative(s) from my organization has attended FAA Aviation Maintenance Human Factors Conferences:	121
0 – 3 times 52%	
4 + times 42%	
Not sure 4%	

Twenty eight percent of 117 respondents felt that they have participated in some aspect of the FAA Human Factors in Aviation Maintenance and Inspection Research Program. This participation ranges from being a site for development and testing to merely using the documents and reports. This percentage is an excellent testimony that the program has had very good industry participation.

5.5.1 Comments about the Program

There were many positive comments about the program in Section 4. Rather than relegating all comments to Appendix 2, the following are particularly important.

"I have used the materials to implement HF training in the USAF. Outstanding materials…"

"FAA information and products are very important and useful. FAA is a reference for my country… We need the major aviation experience from the US."

" We are using FAA CD-ROM data in our classrooms."

"We will be implementing FAA HF research products."

5.6 THE VALUE OF FAA HUMAN FACTORS RESEARCH PRODUCTS

Table 5.3 lists all of the questions in Section 5 of the questionnaire. The program products in Table 5.3 are listed in descending orders of acceptance; however, there are not significant differences in the level of acceptances. Overall, respondents like all of the products.

Table 5.3 Value of Various FAA Human Factors Research Products

PRODUCT	Mean	SD
Overall value of FAA Maintenance Human Factors Research Program	4.4/5.0	.74
The *Human Factors Guide for Aviation Maintenance* Website	4.2/5.0	.82
The www.HFSKYWAY.com Website	4.1/5.0	.87
The annual CD-ROMs on Human Factors in Aviation Maintenance and Inspection	4.1/5.0	.88
Team Training for Maintenance Technicians (AMTT)	4.0/5.0	.87
The *Human Factors Guide for Aviation Maintenance* (CD-ROM)	4.0/5.0	.93

Software for Coordinating Agency for Supplier Evaluation (CASE)	3.7/5.0	.87
On-Line Aviation Safety Inspection System (OASIS)	3.7/5.0	1.07
B- 767 Environmental Control Tutor	3.6/5.0	.78
Software for Maintenance Ergonomics Audit (ERNAP)	3.5/5.0	1.10
System for Training FAA Regulations (STAR)	3.3/5.0	1.01

The highest rating on the entire questionnaire was question 5.11, which rates the overall value of the human factors research program. Response was 4.4/5.0 (SD=.74). Obviously, the research team was pleased with this vote of high overall user acceptance. A similarly high rating was given to the desire for advisory material in question 6.3 (d).

5.6.1 Comments about Value of the Program

There were many positive comments about the program in Section 5. Rather than relegating all comments to Appendix 2, the following are particularly important.

"I am extremely pleased with this year's CD, especially with the training material..."

"Thanks to the US FAA for leading this excellent safety improvement program."

"All very valuable."

5.7 PERCEIVED REQUIREMENTS FOR MAINTENANCE HUMAN FACTORS PRODUCTS

Table 5.4 shows the summary of responses in this section. The high positive answers, ranging from 3.7 to 4.6, indicate that the respondents want most aspects of the program to continue. While certain numbers are higher than others, there is not a statistically significant difference in the responses.

The response associated with the perceived need for Advisory Circulars was tied for the response highest number on the survey. This seems to indicate that industry personnel want to be told, or at least guided, by the regulations with respect to specific Human Factors requirements. The FAA Maintenance Resource Management (MRM) Handbook, published during 1998, is a step in the right direction.

Table 5.4 Perceived Requirements for Maintenance Human Factors Products

Perceived Needs	**Mean**	**SD**
Training Materials		
Hardcopy Training	4.0	90
Computer-based Training (CBT)	3.9	.86
Web-based Training (WBT)	3.7	1.06

Job-aiding		
A. New technology hardware for maintenance environment	3.7	.99
B. New technology software (e.g., scheduling, workflow, process automation, electronic pubs, etc.)	3.8	1.00
C. Information to conduct internal human factors audit	4.1	.93
Information		
A. Enhanced Website	3.8	1.02
B. Annual CD-ROMs on Human Factors in Aviation Maintenance and Inspection	4.2	.68
C. Conferences	4.1	.82
D. Advisory Circulars for Human Factors	4.4	.68

5.7.1 Comments about Future R&D Projects

There were many positive comments about the program in Section 6. Rather than relegating all comments to Appendix 2, the following are particularly important.

"The advisory circulars may be very beneficial in our industry."

"We need support in most areas of human factors."

" This program is key to improving aviation safety…..it must remain."

5.8 SUMMARY AND DISCUSSION

This report has summarized the opinions of nearly 122 aviation maintenance professionals from around the world. The respondent group certainly represents the world of aviation maintenance, especially airline maintenance.

The industry places high value in past, present, and planned FAA research and development related to human factors in maintenance. The industry feels that it has played a major role in the research. It continues to apply the by-products of the research program. The program is a major success by all conceivable measures.

The questionnaire responses are the scientific basis for the results that are reported herein. However, one who has been involved in the program for nearly eleven years notices much more than positive responses on a survey instrument. Aviation maintenance human factors was merely a concept when the researchers began "preaching" to anyone who would listen at the airlines and repair stations in the late '80s. The first FAA Human Factors in Maintenance and Inspection Symposium drew about 36 attendees, most of which were the speakers. Each year the Symposium has grown. Now, co-hosted with Transport Canada and the CAA United Kingdom, the meeting draws nearly 400 participants.

Aircraft manufactures have assumed active leadership roles in maintenance human factors by providing error reporting systems, training, and other information to their customers. Repair stations have invested in human factors audits, conducted training classes, and taken exemplary positions regarding maintenance error reporting systems.

Colleges and universities are now offering programs specializing in maintenance human factors. Students graduating from most FAA-approved Part 147 schools have a basic understanding of human factors. During 1999 there will be a Web-based interactive course on maintenance human factors attended by maintenance personnel worldwide.

Regulators have recognized the importance of human factors in maintenance. Joint Aviation Regulations (JAR) 66 now requires a level of human factors knowledge necessary for certification. Other regulations are likely to follow throughout the world. More impressive is the fact that many aviation organizations are recognizing the safety and financial payoff, and are implementing human factors training in advance of regulatory intervention.

Government regulators, the aviation industry, and the research team have a right to be proud of the progress made in maintenance human factors since 1988. The awareness, education, and various work place interventions are not yet complete. As long as humans are part of the maintenance equation, there will always be opportunities for improvement via strict attention to “human factors.”

5.8.1 Continuing Research and Development

The FAA Office of Aviation Medicine Human Factors in Aviation Maintenance and Inspection Research and Inspection Program has a legacy of success. The key factor that has influenced the success is the nature of the research, which has applied basic scientific principles to solutions for the aviation maintenance work environment. The research program has capitalized on a diverse research team comprising industry and academia. Researchers have used the industry maintenance environments as the primary laboratory for activities. In most cases new ideas and solutions are generated and tested in concert with industry partners. Reports have been written so that they “make sense” to readers in the aviation maintenance community. The research program has published results in an integrated fashion that exists on CD-ROMs and in full-text on the Internet. Few programs have such a legacy.

The research program is unique because it has never lost focus on who the customer is. The primary customer is the aviation maintenance community comprised of technicians and managers. This primary customer values the work and applies the results.

Occasionally the research program has received criticism—some constructive—from academic researchers, both within and outside of the FAA. Comments have focused on the applied nature of the program’s techniques and products. Since the inception of the program, the FAA program managers have never lost sight of the importance of basic scientific principles, but have committed the program to applied results. The value of this firm commitment, by the Office of Aviation Medicine, to applied human factors research has been validated by this industry assessment, thereby demonstrating the right balance between science and practice.

To ensure successful contribution to safety and efficiency in aviation maintenance, the human factors research program should capitalize on the philosophies and practices that have worked so well for the first decade of the program.

5.9 ACKNOWLEDGMENT

The authors gratefully acknowledge the industry associations, numerous airlines, manufacturers, governments, and individual aviation maintenance professionals who have contributed to the success of this research program.

5.10 APPENDIX 1 QUESTIONNAIRE WITH SELECTED SUMMARY DATA

Questionnaire on Human Factors in Maintenance and Inspection

Section 1. General Information

Date:__________________ Name (optional):___________________________

Title (optional):____

Organization (optional):____

Type of Organization (check only one):

q Airlines	q Government
q Manufacturer	q Academic
q Repair Station	q Consulting
q Supplier	q Other __________________

Years of Human Factors experience ____________Years of aviation experience__________

Section 2. Purpose of this Questionnaire

The purpose of this questionnaire is to assess the following:

- Current status of Human Factors maintenance programs in your organization.
- Your knowledge of FAA Aviation Maintenance Human Factors research products.
- Your perceived requirements for FAA Aviation Maintenance Human Factors research.

Section 3. Current status of Human Factors maintenance programs in your organization

Please add comments at the end of the section.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
3.1a Our maintenance Human Factors program is very active	O	O	O	O	O
OR					
3.1b We are planning a Human Factors program for maintenance personnel	O	O	O	O	O
3.2a We have an active Human Factors training program being delivered to maintenance personnel	O	O	O	O	O
OR					
3.2b We are planning Human Factors training for maintenance personnel	O	O	O	O	O
3.3 Our organizations has at least one person with full time responsibility for maintenance Human Factors	O	O	O	O	O

3.4 Our organization has a high interest in maintenance Human Factors	O	O	O	O	O

	Yes	No	Not Sure
3.5 We use the "Dirty Dozen Posters" somewhere in our organization	O	O	O
3.6 We use information from the FAA Human Factors:			
CD-ROMs (comment below)	O	O	O
Hard copy reports (comment below)	O	O	O
Website (comment below)	O	O	O
Conferences (comment below)	O	O	O

Please add comments at the end of the section.	**Yes**	**No**	**Not Sure**
3.7 We have sent people to specialized Human Factors courses	O	O	O
3.8 We have brought in consultants to deliver Human Factors courses	O	O	O
3.9a We have a formal Human Factors error reporting system	O	O	O
OR			
3.9b We are planning a formal Human Factors error reporting system	O	O	O
3.10 We have a formal discipline system that acknowledges the importance of error reporting	O	O	O
3.11 We have data:			
From our error reporting system	O	O	O
Showing how Human Factors related errors raise costs	O	O	O
Show how Human Factors interventions lower costs	O	O	O
3.12 We have conducted a Human Factors audit of our maintenance organization	O	O	O
3.13 We plan to conduct a Human Factors audit within the next 18 months	O	O	O

Explanations, comments, or suggestions for Section # 3

Section 4. Your knowledge of the FAA Human Factors R&D products

Please add comments at the end of the section.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
4.1 I am knowledgeable about Human Factors conditions that existed 10 years ago	O	O	O	O	O
4.2 I am knowledgeable about Human Factors conditions that existed 5 years ago	O	O	O	O	O
4.3 I find the FAA reports on the Maintenance Human Factors program very useful	O	O	O	O	O

	Yes	**No**	**Not Sure**
4.4 I have received at least 3 CD-ROMs from the FAA concerning Aviation Maintenance Human Factors	O	O	O
4.5 My organization has participated in at least one FAA Human Factors research activity.	O	O	O
4.6 Representative(s) from my organization has attended FAA Aviation Maintenance Human Factors Conferences:			
0 - 3 times	O	O	O
4 + times	O	O	O

Please add comments at the end of the section.	**Yes**	**No**	**Not Sure**
4.7 Have you implemented FAA Aviation Maintenance Human Factors research products/interventions (comments)	O	O	O

Explanations, comments, or suggestions for Section # 4

Section 5. The value of various FAA Human Factors research products

Please rate your familiarity and value of the following FAA Human Factors research products

Please add comments at the end of the section.	Very Low		Medium		Very High	N/A
5.1 B-767 Environmental Control Tutor (1994)						
Familiarity	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.2 System for Training FAA Regulations (STAR)						
Familiarity (1996)	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.3 Team Training for Maintenance Technicians (AMTT)						
Familiarity (1997)	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.4 Software for Coordinating Agency for Supplier Evaluation (CASE) (1997)						
Familiarity	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.5 Software for Maintenance Ergonomics Audit (ERNAP)						
Familiarity (1996)	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.6 On-Line Aviation Safety Inspection System (OASIS)						
Familiarity (1995)	O	O	O	O	O	O
Value	O	O	O	O	O	O

5.7 The *Human Factors Guide for Aviation Maintenance*

(CD-ROM version) (1995-1997)						
Familiarity	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.8 The *Human Factors Guide for Aviation Maintenance* (Website version) (1998)						
Familiarity	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.9 The annual CD-ROMs on Human Factors in Aviation Maintenance and Inspection (1992-1997)						
Familiarity	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.10 The www:HFSKYWAY.com website (1996-1998)						
Familiarity	O	O	O	O	O	O
Value	O	O	O	O	O	O
5.11 What is the overall value of the FAA Maintenance Human Factors research program	O	O	O	O	O	O

Explanations, comments, or suggestions for Section # 5

Section 6. Perceived requirements for Aviation Maintenance Human Factors products

Please indicate your agreement or disagreement with the following:

Please add comments at the end of the section.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
My organization needs Maintenance Human Factors support in the following areas:					
6.1 Training Materials	O	O	O	O	O
Hardcopy training	O	O	O	O	O
Computer-based training (CBT)	O	O	O	O	O

Web-based training	O	O	O	O	O
6.2 Job-aiding					
A. New technology hardware for maintenance environment	O	O	O	O	O
B. New technology software (e.g., scheduling, workflow, process automation, electronic pubs, etc.	O	O	O	O	O
C. Information to conduct internal Human Factors audits	O	O	O	O	O
6.3 Information					
A. Enhanced Website	O	O	O	O	O
B. Annual CD-ROMs on Human Factors in Aviation Maintenance and Inspection	O	O	O	O	O
C. Conferences	O	O	O	O	O
D. Advisory Circulars for Human Factors	O	O	O	O	O

Explanations, comments, or suggestions for Section # 6

Once you have completed this form, please return to:

Ms. Kiesha Higgins
2130 LaVista Executive Park Drive
Tucker, GA 30084
Phone: (770) 491-1100
Fax: (770) 491-0739
e-mail: Kiesha.Higgins@GalaxyScientific.com

Are you on the FAA Mailing List for Human Factors in Maintenance (Y/N)__________

To be added, send name and address to:

Receptionist
2130 LaVista Executive Park Drive
Tucker, GA 30084
Phone: (770) 491-1100
Fax: (770) 491-0739
e-mail: Atlanta.Receptionist@GalaxyScientific

5.11 APPENDIX 2: WRITTEN RESPONSES CLASSIFIED BY QUESTION NUMBER

	Basic Information	Section #3	Section #4	Section #5	Section #6
1	Event UK Country USA Type of Organization. Government/Academic HF Experience 2 Aviation Experience 15	Outstanding sources for instructional information! Will be adding causes and corrections to database system that is visible to all maintenance personnel. System just reports cost, location and when error occurred now.	I have used the materials to implement HF training in the USAF outstanding material	I am extremely pleased with this year's CD especially with the training material. The more personnel trains in HF, the safer the Aircraft Maintenance world will be	
2	Event ATA Country USA Type of Organization Airlines HF Experience 2 Aviation Experience 30	The commitment for Maintenance Human Factors Awareness and training is not shared by Sr. Mgt. Due to low perception of it's R.O.I. IE: It will cost to implement but has no concrete payback period		Research will be of more value once we get Human Factors program up and running. Without a program the research has low value.	Advisory circular will go a long way "in selling maintenance Human Factors Program to the financial side/Sr. Mgt. of the Business as it will give a clear outline as to what program should look like
3	Event UK Country UK Type of Organization Regulatory Authority HF Experience 30 Aviation Experience 40		We do our own research in UK CAA		
4	Event UK Country UK Type of Organization Regulatory Authority HF Experience --- Aviation Experience 29				Products can help, but Human Factors output is cultural change not too interested in the products issue
5	Event UK Country -------	We are starting to recognize Human Factors influence in incidents- informally it has		Our company does not allow employees access to the web only individual Email addresses	

	Type of Organization Repair Station HF Experience --- Aviation Experience 32	been recognized as a problem			
6	Event UK Country UK Type of Organization Repair Station HF Experience 1 Aviation Experience 23	Company has a audit scheduled for Mid-march 98		FAA Research products were not available at our company last year	All aviation maintenance HF products are addressed for use by Operators/Airlines. Have you considered issuing HF for Repair and Overhaul facilities? If yes, please let us know thanks
7	Event UK Country Wales Type of Organization Repair Station HF Experience --- Aviation Experience ---	Our company has been refreshed in one previous HF course. We are currently reviewing our approach to HF especially now that ICAO charges are imminent	Our company has not yet adopted any formal journal monitoring of HF issues nor have we promoted HF issues within the workplace	With the exception of CASE. We as a company have not reviewed the research products	Guidance on how to implement a HF audit plan which included checks would be useful
8	Event UK Country USA Type of Organization Repair Station HF Experience 18 Aviation Experience 41			If it were not for this program activity on MHF the US would be 100% less. We would be far behind the rest of the world.	This is key to improving aviation safety. The industry can only improve from this program. It is and must remain
9	Event UK Country USA Type of Organization Manufacturer HF Experience 3 Aviation Experience 12	We have not yet brought in consultants to deliver HF courses A formal discipline system is in development and we are planning a HF audit	We will be implementing FAA HF research products		
10	Event UK Country Brazil	I knew about HF programs in	FAA information and products are	I would suggest a kind of "MEDA: software	But we are still in process of diffusing the HF

	Type of Organization Airlines HF Experience 1 Aviation Experience 12	aviation maintenance last year during a maintenance training conference in Germany Since then I got very interested and I'm getting more involved in this subject. My aim is to have some implementation in the near future. By the moment I'm doing my best to apply some fundamentals on my day-to-day business and to my subordinates	very important and useful. FAA is a reference for my country. We don't have a very developed industry within our country. We need experience. The major aviation experience comes from US	to be included in the CD. That would be a guide for incident investigation within components of the same time. It could be a source for a database that could be used to determine the HF main issues within the organization. The results could be retrieved by the FAA as part of your research and for information share.	principles and culture within our organization to have more top level involved.
11	Event UK Country UK Type of Organization Confidential Reporting HF Experience 2 Aviation Experience 40	Our organization is a confidential reporting agency (similar to ASRS)	UK based organization is involved with UIC research		
12	Event UK Country UK Type of Organization Repair Station HF Experience 2 Aviation Experience 16		We have requested CD-ROMS but have not received them for the London office		
13	Event UK Country France Type of Organization Repair Station HF Experience 1 Aviation Experience 20		Implementation in progress	Thanks to US organization for leading the excellent safety improvement program	
14	Event UK Country UK	Paucity of information on documented rotary incidents on	Specialist courses on rotary aircraft maintenance would be helpful		

	Type of Organization Commercial Operator HF Experience 2 Aviation Experience 30	maintenance errors			
15		This is a new area for us which we are just beginning to look at-this applies to all questions			
16	Event UK Country UK Type of Organization Airlines HF Experience 5 Aviation Experience 35	Although we recognize the cost issues, we do not as yet have an effective means of measuring them, or a desire to.			
17	Event UK Country USA Type of Organization Manufacturer HF Experience 2.5 Aviation Experience 11	We are more active in supporting our external customers than we are internally to date. We can't seem to get the factory and flight line signed up to MEDA type systems.	The FAA supported the development of MEDA	For the things that I am not familiar with, I cannot evaluate their value. We do distribute the FAA CD's to our MEDA customers.	The advisory circulars may be very beneficial in our industry.
18	Event UK Country UK Type of Organization Repair Station HF Experience 2 Aviation Experience 30				Our company decision on HF policy still to be determined
19	Event UK Country UK Type of Organization Academic HF Experience	We will be delivering a basic training program on HF as educationalists we are well aware of HF influence. Training programs in accordance with JAR66 module 9		My intent is to use some majority of these products for the design and delivery of HF training programs. Please keep me informed	I have now discovered how much we need all the information we can get on Aviation Maintenance Human Factors products

	1 Aviation Experience 30				
20	Event UK Country Ireland Type of Organization Airlines HF Experience 6 Aviation Experience 46			Did not know about it	
21	Event UK Country Hong Kong Type of Organization Repair Station HF Experience 2 Aviation Experience 25	Our program is just starting up.		Section not completed as I have not used these systems or websites	
22	Event UK Country UK Type of Organization Government HF Experience 3 Aviation Experience 25	Lots of these are not entirely relevant to the CAA's role. CAA is actively exploring initiatives to encourage industry to address HF issues	12th Symposium held in UK is proof of CAA commitment to HF		All initiative to share information is beneficial. Long term position must be web driven but interim aviation still requires non IT-based support. Coordinated global training standards must be the way. Let's set the goal
23	Event UK Country UK Type of Organization Airlines HF Experience --- Aviation Experience 27	As a UK operator "Human Factors" is something we are all aware of. But to date have not focused on			Early days yet for our organizations but this symposium has generated both knowledge and motivation to introduce error management into our culture
24	Event UK Country USA Type of Organization Airlines	FAA Materials are excellent	Using CD-ROM data in classrooms	Please explain computer HF requirements for CD version on website	

	HF Experience 3 Aviation Experience 13				
25	Event UK Country UK Type of Organization Repair Station HF Experience --- Aviation Experience 28	We have completed two product and process audits to date of own design	Knowledgeable of Human Factors conditions by experience only and would like to study the FAA reports further	We have not at this time reviewed any of the listed data	At this time we do not have ready access to a web capability
26		This symposium is our company's introduction to Human Factors in the Maintenance Environment. However a number of related duties and tasks performed by different individuals within our organization made some of the requirements of Human Factors very loosely.			
27	Event France Country France Type of Organization Manufacturer HF Experience 20 Aviation Experience 49	Not sure of the accuracy of hard Copy reports		All very valuable	
28	Event Qantas Country Malaysia Type of Organization Airlines HF Experience --- Aviation Experience ---	We have not sent people for specialized HF courses, but have a few who have attended short ATA courses as well as Int. Fed. of Airworthiness (IFA) conferences. We have brought in HF specialists from Boeing to conduct HF Awareness and	Our usage of the FAA products is limited to HF guide for Aviation Maintenance, AMT, and HF in Aviation Maintenance and Inspection	We definitely find the products available to us very useful, but we certainly lack exposure to most, including access to website. As we have limited PC terminals that are linked.	Self Explanatory support in most areas of HF

		MEDA course. We plan to bring in Dr. William Johnson from Galaxy Scientific Corporation			
29	Event France Country France HF Experience 10 Aviation Experience 30	Being a vendor training organizations, we do not offer the maintenance staff, we cannot therefore easily monitor but have been looking to offer HF training			Being outside the US, this material has not been readily available we hope to change this.
30	Event France Country France Type of Organization Airlines HF Experience 3 Aviation Experience 30	4000+ AMT-T's attended HF workshop QA Department using MEDA for incident/accident investigations Coop effort/team consisting of Mgt. + union			Although I (we) are not using all of the FAA HF products I (we) do appreciate the FAA's interest and development of materials; our time has been consumed with MEDA and initial HF Training
31	Event ATA Country USA Type of Organization Airlines HF Experience 3 Aviation Experience 9	We have openly invited Non-NWA employees to attend our seminars, other Airlines, Military, Grey Owl, doors are open.			
32	Event ATA Country USA Type of Organization Airlines HF Experience 2 Aviation Experience 30		All research products that had US Airways involvement (MRM training, design development, document design aid, etc.) were fully implemented. This research was invaluable	Although CD-ROM's provide research tools (hyperlinks) I believe documents like the Human Factors Guide for Aviation Maintenance should be available in hard copy.	The FAA must expand their research efforts in human factors issues. To date, their research has been invaluable to the industry. The FAA resources must increase to ensure continuation of the programs to date. Programs currently in place at USAir 1. HF Training (Robertson). 2. Roundtable problem solving

					3. Use of Document Design Aid (Drury) 4. Evaluation of MRM Training (Taylor) 5. “Hotline” into Q.A, for flight safety concerns 6. Ground damage data collections 7. Partnership programs for problem solving.

CHAPTER 6
ANALYSIS OF SHIFT CHANGE IN THE AIRCRAFT MAINTENANCE ENVIRONMENT: FINDINGS AND RECOMMENDATIONS

Anand K. Gramopadhye and Kuldeep Kelkar
Clemson University

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

6.1 EXECUTIVE SUMMARY

This chapter is divided into three major sections. The Executive Summary provides a brief background for the study and outlines the methodology adopted. The next section focuses on the analysis of the shift change operation, detailing the task analysis and the error taxonomy. The Discussion section outlines specific interventions and a standardized procedure for a safer and more efficient shift change. The research was conducted with various industry partners to ensure its relevance and applicability to the aviation maintenance community.

For the FAA to provide the public with a safe, reliable air transportation system, it is important to have a sound aircraft inspection and maintenance system.9 The inspection/maintenance system is a complex one with many interrelated human and machine components. The linchpin of this system, however, is the human. Recognizing this, the FAA under the auspices of National Plan for Aviation Human Factors has pursued human factors research.9,10 In the maintenance arena this research has focussed on the aircraft inspector and the aircraft maintenance technician (AMT).5,22,23 Since it is difficult to eliminate errors completely, continuing emphasis must be placed on developing interventions to make the inspection/maintenance procedures more reliable and/or more error-tolerant.

Aircraft for commercial use have their maintenance scheduled initially by a team that includes the FAA, aircraft manufacturers, and start-up operators. These schedules are then taken by the carrier and modified so that they suit individual carrier requirements and meet legal approval. Thus, within the carriers' schedules, there will be checks at various intervals, often designated as flight line checks; overnight checks; A, B, C and, the heaviest, D checks. The objective of these checks is to conduct both routine and non-routine maintenance of the aircraft. This maintenance includes scheduling the repair of known problems; replacing items after a certain air time, number of cycles, or calendar time; repairing defects discovered previously, for example from reports logged by pilot and crew or from line inspection, or items deferred from previous maintenance; and performing scheduled repairs.

Task analysis of maintenance activities has revealed aircraft inspection to be a complex activity requiring above average coordination, communication and cooperation between inspectors, maintenance personnel, supervisors and various other sub-systems (e.g., planning, stores, clean-up crew, shops) to be effective and efficient. A large portion of the work done by inspectors and maintenance technicians is accomplished through teamwork. The challenge is to work autonomously but still be a part of the team. In a typical maintenance environment, first, the inspector looks for defects and reports them. The maintenance personnel then repair the reported defects and work with the original inspector or the buy-back inspector to ensure that the job meets predefined standards. During the entire process, the inspectors and maintenance technicians work with their colleagues from the same shift and the next shift as well as personnel from planning, stores, etc. as part of a larger team to ensure that the task gets completed.9 Thus, in a typical maintenance environment, the technician has to learn to be a team member, communicating, and coordinating the activities with other technicians, and inspectors.

One of the areas requiring the use of effective team skills is shift change, but this procedure has been widely reported as a cause of several errors/accidents in the aircraft maintenance industry (see 9,10,16 and the recent Continental Express crash). This can be attributed to a lack of well-defined shift change procedures for use by the aircraft maintenance industry. In response to this need, industry has developed ad-hoc measures and general guidelines to assist various personnel involved in the shift change process. This has resulted in various organizations developing their own internal procedures, which vary in their level of instruction/detail. Because of this situation, shift change procedures are not standardized across the industry. Moreover, they are often not based on sound principles of human factors design. Hence, there exists a need to look at the shift change process. In response to this need, this research looked at the entire shift change process to identify human factors interventions that can be applied to develop a standardized shift change process which will minimize shift change errors. The specific objectives of this research were as follows:

To analyze the shift change process at representative aircraft maintenance sites.

To develop a taxonomy of errors and identify human factors interventions to prevent them.

To document a standardized shift change process.

The methodology to support the objectives is described in the following section.

6.1.1 Methodology

As a first step, the study analyzed the shift change process at representative aircraft maintenance sites, including the communication norms, information transfer procedures, shift change procedures, guidelines and FAA-mandated procedures. Next, a detailed error taxonomy was developed to help classify the typical shift change errors. The errors were analyzed and interventions identified to develop a standardized shift change process that not only minimized errors but also was error-tolerant. Throughout this research, the researchers focused on the mechanic/inspectors, their respective supervisors, and the various entities that they interact with. As a final step, detailed guidelines and procedures were developed to outline a standardized shift change process that can serve as a benchmark for the industry. The specific tasks are outlined below.

Task 1: Form Core Team
Coordinate activities with team partners. Select a cross-functional team with representative from different departments.

Task 2: Study Existing Shift Change Process
Select representative aircraft maintenance sites and study existing shift change procedures. Study representative sample of groups at different sites and for different times.

Task 3: Document Existing Process
Document existing norms, procedures, protocols, hand-over procedures and company-wide internal procedures adopted at representative sites.

Task 4: Develop a Taxonomy of Errors
Develop a taxonomy of errors and classify potential errors. Use a questioning approach methodology asking why, what, where, how, when, who to gather information on errors.

Task 5: Identify Human Factor Interventions
Identify potential human factor interventions to minimize errors and to develop an error-tolerant system.

Task 6: Develop a Standardized Shift Change
Using results from Task 5, define a standardized shift change procedure.

Task 7: Document a Standardized Process
Document the standardized process, job aids and other requirements to support the revised shift change process.

6.2 ANALYSIS OF THE SHIFT CHANGE OPERATION

A detailed task analysis of the operations was conducted with data collected using shadowing, observation, and interviewing techniques. The team partners provided the research team with access to their facilities, personnel, and documentation and allowed the research team to analyze their existing shift change protocol. The team analyzed shift change at three different maintenance sites at different times of the shift. Site A had three shifts, sites B and C each had two. The research team worked with the manager, line supervisor/shift foreman, inspectors, and aircraft maintenance technicians. The research team visited sites that had both light and heavy inspection and maintenance work. During a typical site visit, the research team followed one or more inspectors and maintenance technicians, attended shift meetings, and asked probing questions, if necessary, during direct observations. Following this step, the researchers conducted follow-up interviews with the various personnel involved to ensure that all aspects of the shift change process were covered. These interviews covered issues concerning the tasks they were undertaking or had just performed and general issues concerning their work environment, both physical and organizational. All data was contributed anonymously, and system participants were honest, motivated to assist the research team, and concerned about improving aviation safety.

6.2.1 Shift Change – Scope of the Analysis

The scope of the analysis was restricted to shift changes on the hangar floor of an aircraft maintenance facility. Thus, this analysis focuses on activities related to those of inspectors, AMTs and foreman or shift supervisors during shift change.

However, for the purpose of brevity, only those of an inspector are outlined in this report. The study does not analyze specific work conducted by individuals on a shift; rather it is based on data collected by observing various personnel at different sites over several shift turnarounds. Different teams and different activities were observed between the day and night shifts, enabling the research team to observe shift change procedures between different outgoing and incoming shifts.

6.2.2 Task Analysis

The study was initiated with a meeting between the members of the research team and the airline personnel to outline the objectives and scope of the study. The objective was to identify human-machine system mismatches that could lead to errors through shadowing, observing, and interviewing techniques. The goal of the task analysis, which was to understand how the existing system works, was achieved using a formal task analytic approach.14 The first step in this approach is to develop a description of the task that outlines in detail the steps necessary to accomplish the final goal. While various formats can be used to describe a task, in the current case a hierarchical and column format was used in conjunction. Figures 6.2 through 6.6 show the HTA for the shift change operation. Each step was later described in detail using a column format similar to that used by Drury.9 The column format identifies the specific human subsystem required for the completion of each step. The specific subsystems are attention, sensing, perception, decision, memory, control, feedback, communication, and output (Table 6.1 through Table 6.4).

The entire shift change process was analyzed using an integrated approach that combined the classic information transmission model and the system model of human error in maintenance and inspection.5 Figure 6.1 provides a graphical description of the shift change process using these two approaches. The shift change is essentially a hand-over process wherein information on work activity including information on job status, personnel status, material/tools, and equipment as well as the work itself is transferred from one shift (the personnel on Shift A) to another (the personnel on Shift B). In order for shift change to be successful, it is critical that the work and information be correctly transferred. When viewed within the context of the information transmission model, this transmission can be ineffective or inefficient because of two reasons: information loss and system noise. Thus, any system designed to promote (something left out?) should try to eliminate these two causes so that information and work from the input side, Shift A, is correctly transferred to the output side, Shift B. Moreover, an understanding of errors during shift change can be obtained only by understanding the impact of various system-level components on shift change. The specific components considered were those identified by Drury10 as described in Figure 6.1.

Following the analysis of shift change, a comprehensive error classification scheme was developed to classify the potential errors by expanding each step of the task analysis into sub-steps and then listing all the failure modes for each sub-step using the Failure Modes and Effects Analysis Approach.16 Following this, a classification scheme for errors was developed based on Rouse and Rouse's20 human error classification scheme.

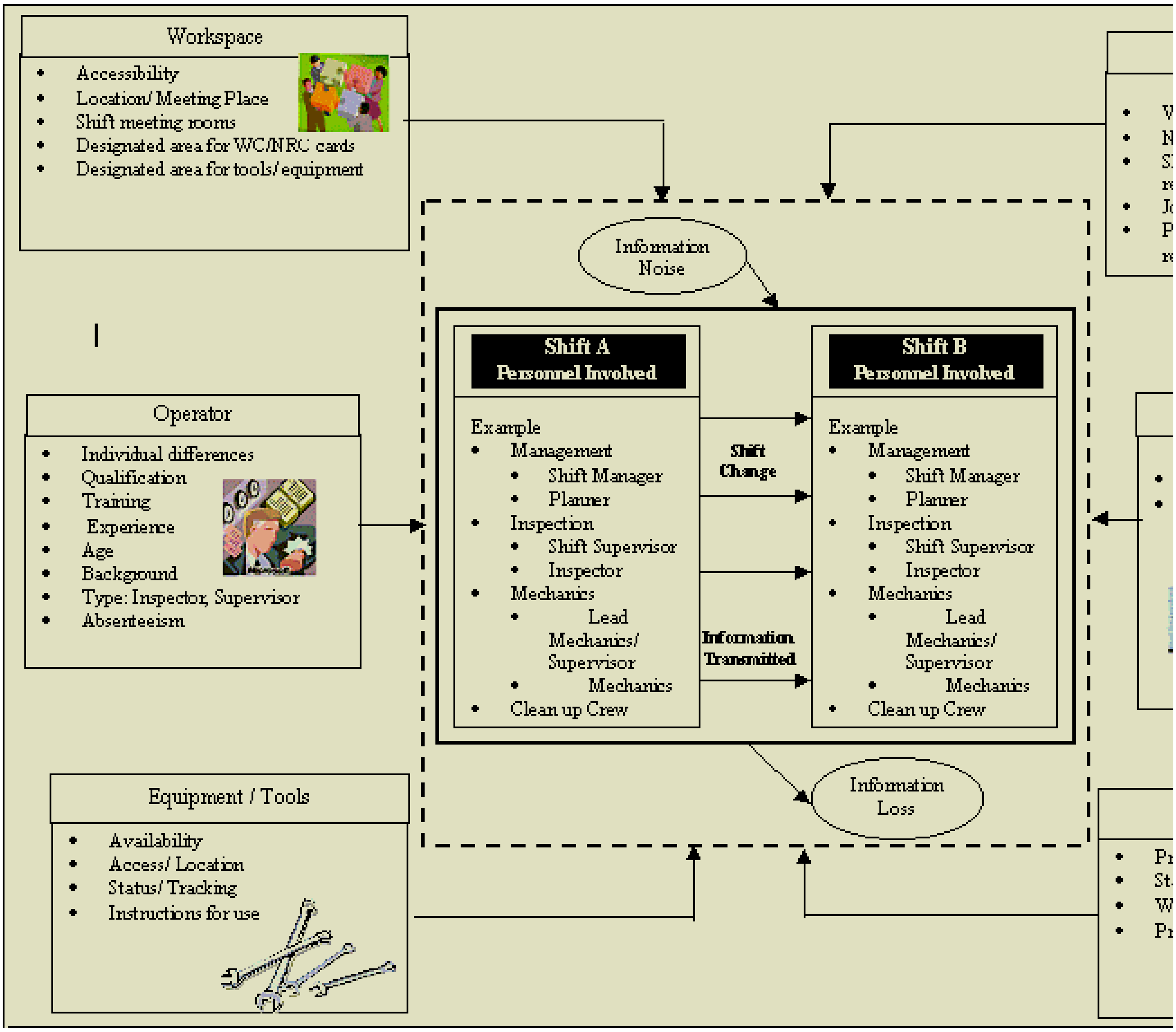

Figure 6.1 A model for understanding shift change

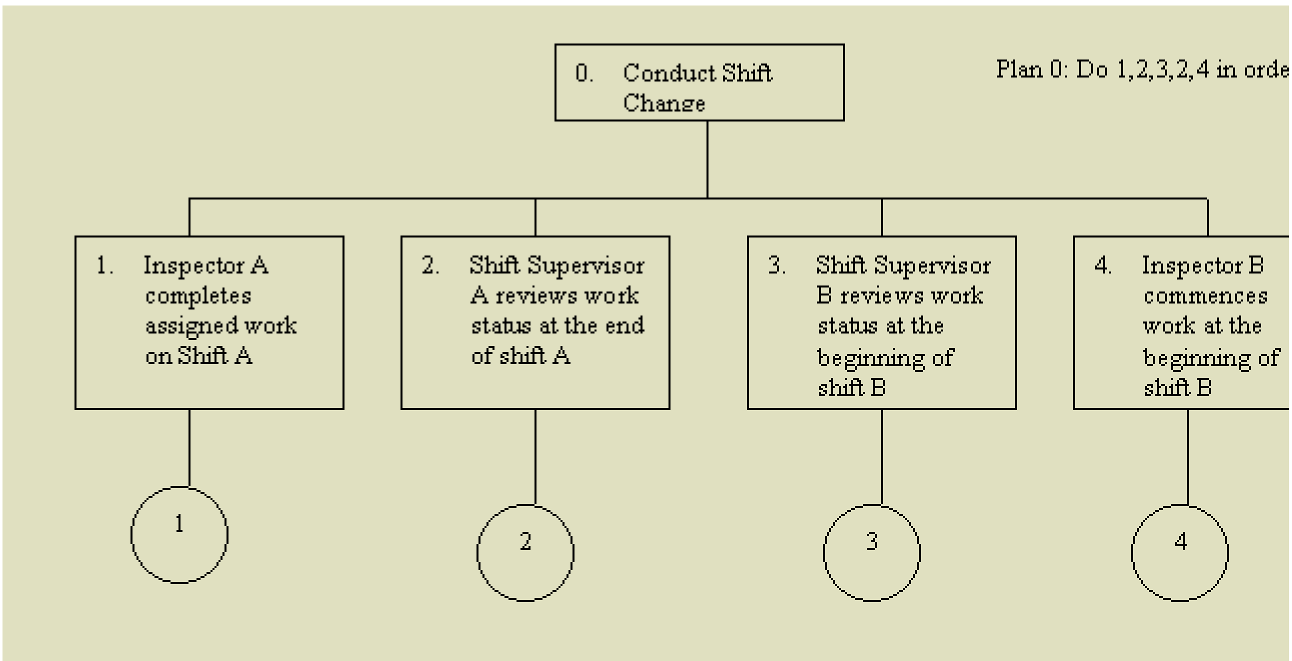

Figure 6. 2 Hierarchical description of the shift change process (0)

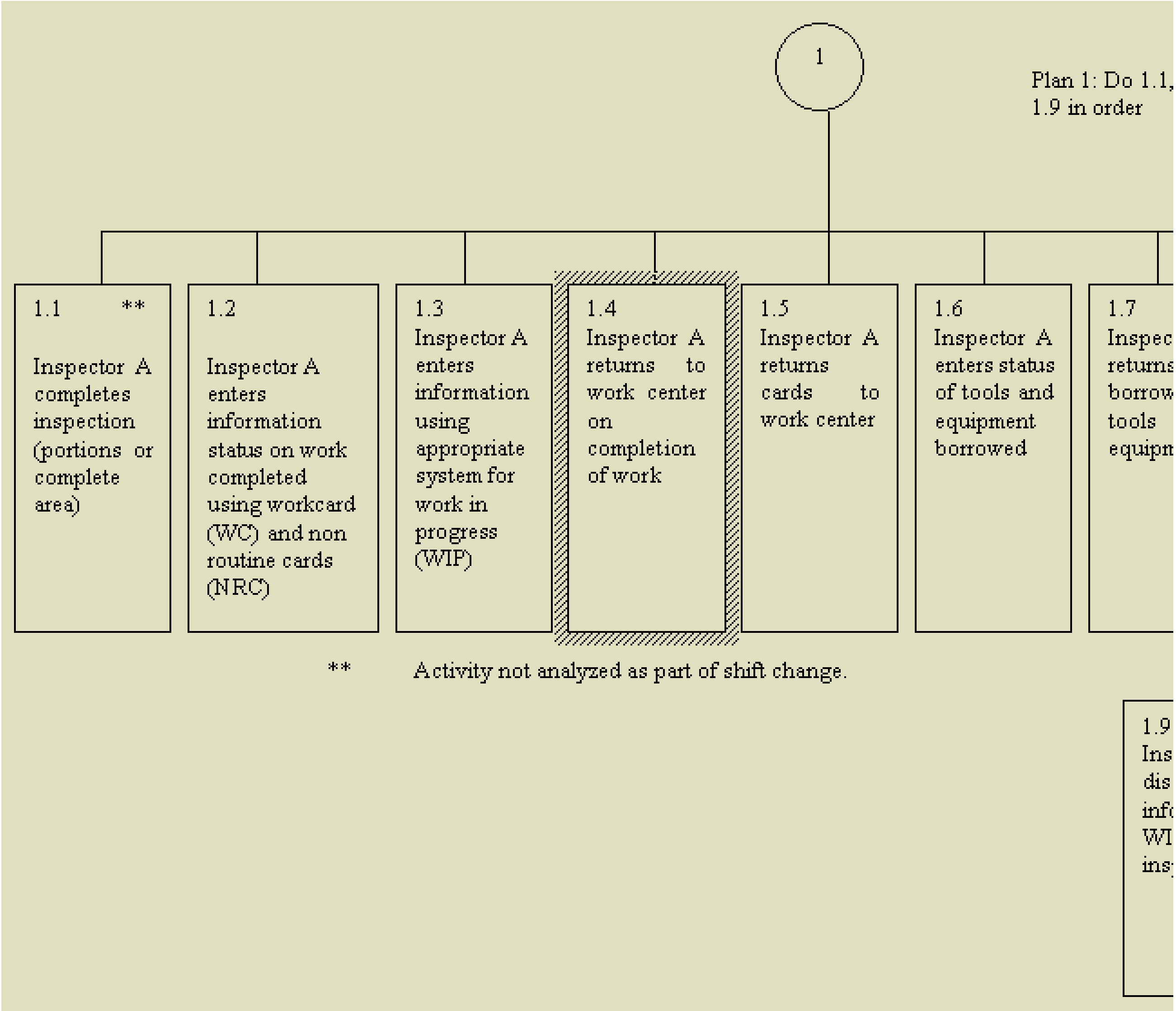

Figure 6.3 Hierarchical description of the shift change process (1)

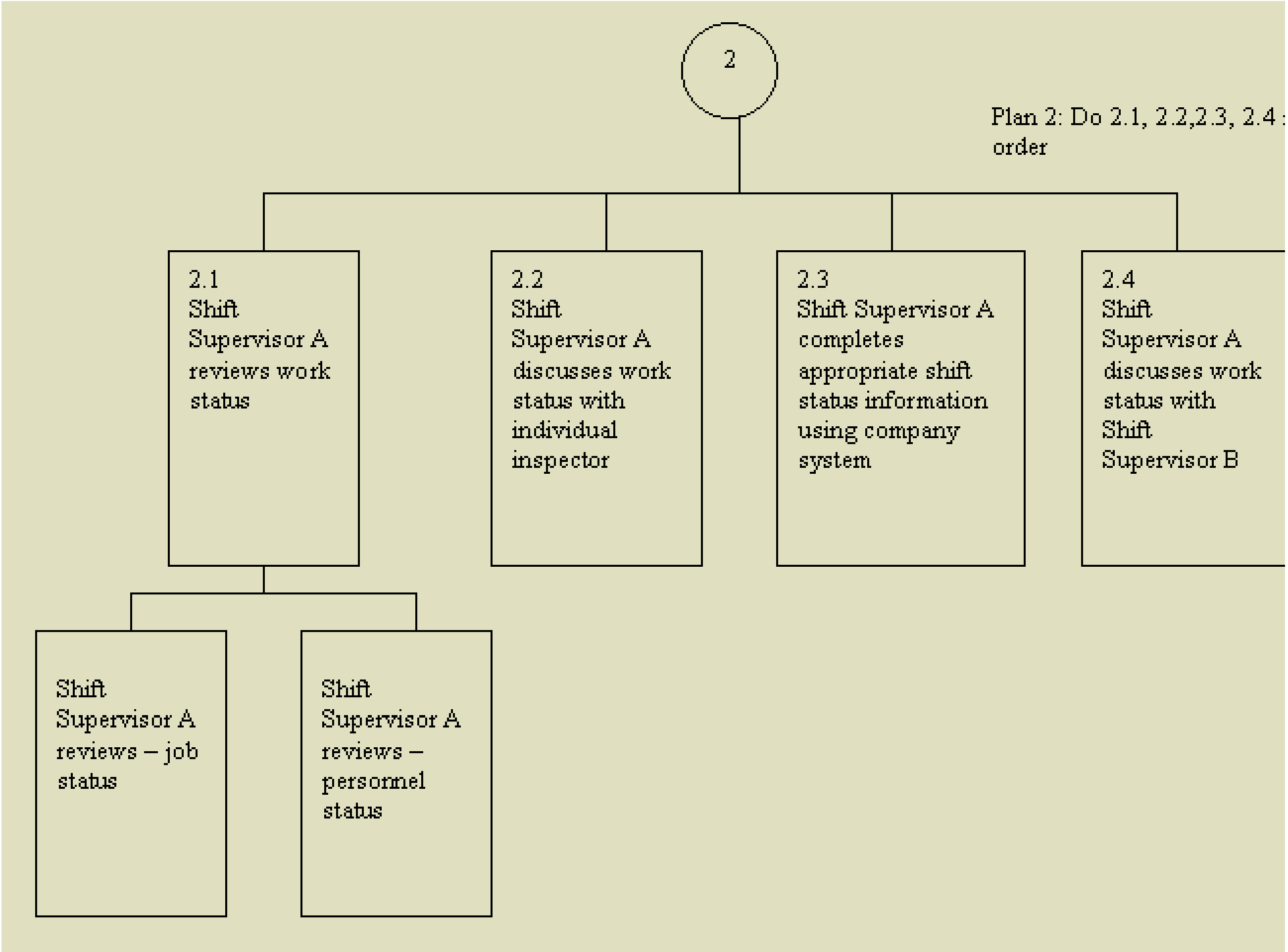

Figure 6.4 Hierarchical description of the shift change process (2)

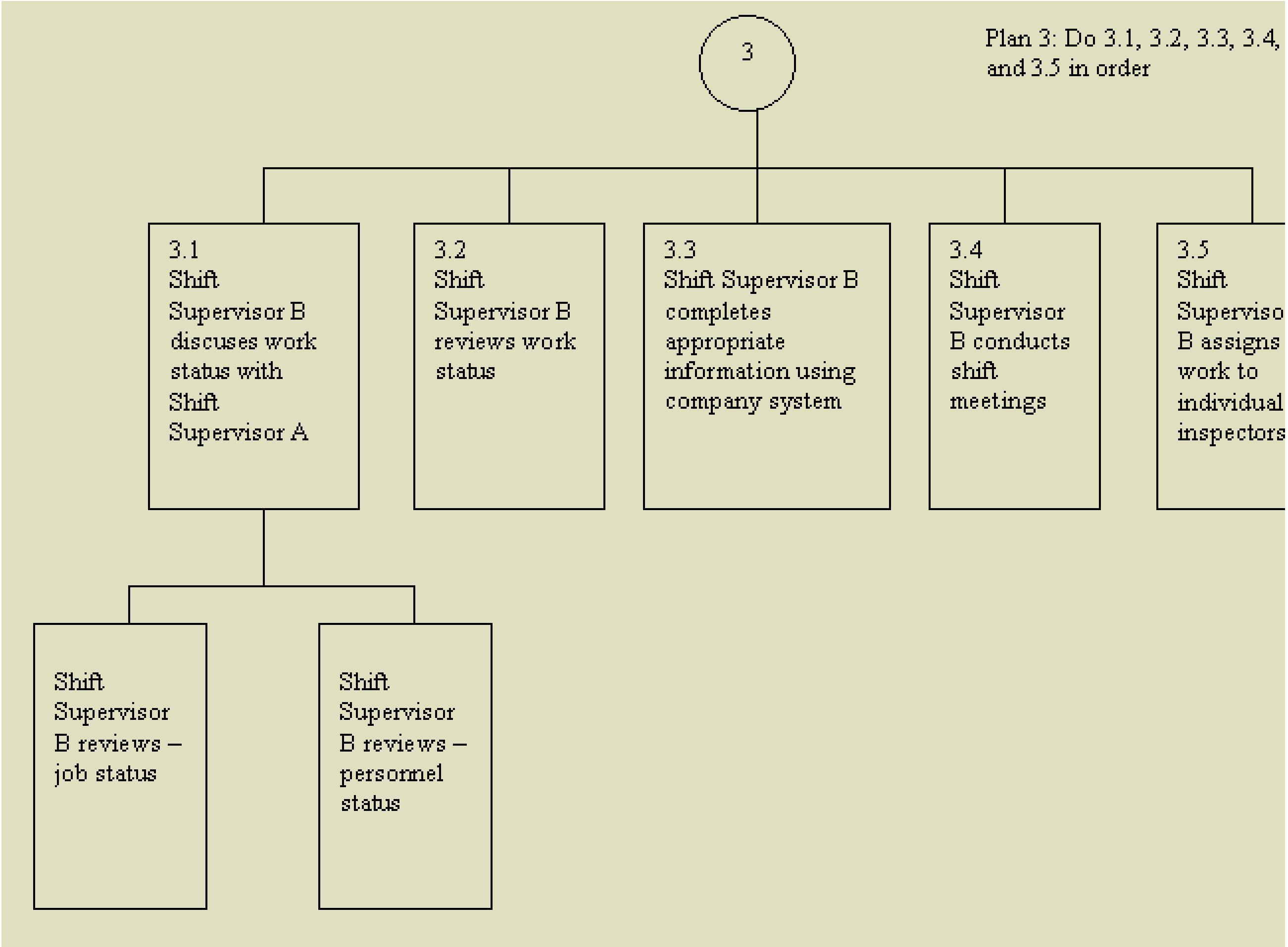

Figure 6.5 Hierarchical description of the shift change process (3)

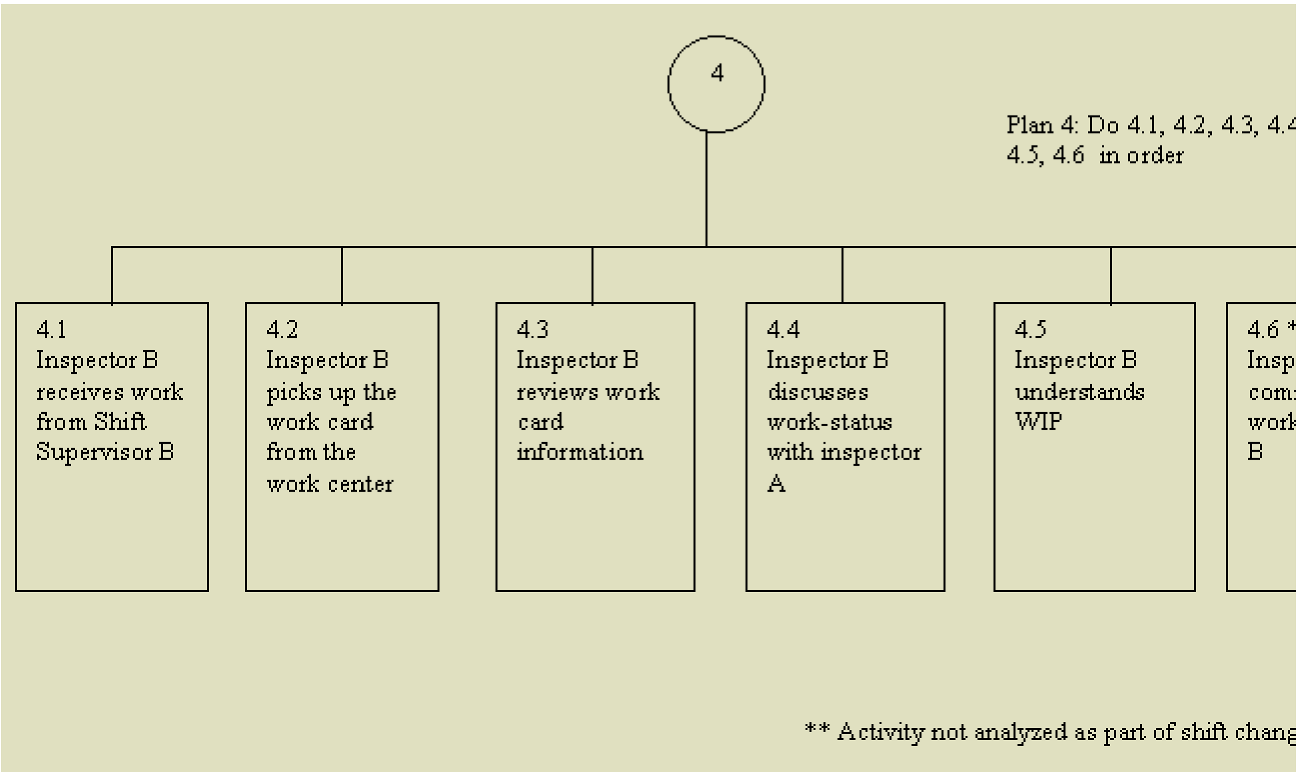

Figure 6.6 Hierarchical description of the shift change process (4)

Table 6.1 Task Analysis of the Shift Change Process

	Task Analysis								
TASK DESCRIPTION	A	S	P	D	M	C	F	O	OBSERVATIONS
1.0 Inspector A completes assigned work on shift A									
1.1 Inspector A completes inspection (portions or complete area)**									
1.2 Inspector A enters information status on work completed using work card (WC) and non routine cards (NRC)	*	*	*	*	*			*	
1.3 Inspector A enters information using appropriate system for work in progress (WIP)	*	*	*	*	*				Inspector completes information on items not completed, items started but not signed off.
1.4 Inspector A returns to work center on completion of work	*							*	
1.5 Inspector A returns cards to work center.	*							*	
1.6 Inspector A enters status of tools and equipment borrowed	*	*	*	*	*				
1.7 Inspector A returns borrowed tools and equipment	*			*				*	If no work in progress and tools are not required, they are returned to store, else a decision is made whether to retain the tools.
1.8 Inspector A briefs shift supervisor on work status	*				*		*		
1.9 Inspector A briefs Inspector B on ongoing work status									

TASK DESCRIPTION	A	S	P	D	M	C	F	O	OBSERVATIONS
1.9.1 Inspector discusses written information on ongoing work with Inspector B	*	*	*	*	*		*		No fixed location or protocol fo meeting (informal discussion)
1.9.2 Inspector A debriefs Inspector B at inspection site on ongoing work.	*	*	*	*	*		*		Access to site may not be possible due to parallel work

** Activity not analyzed as part of shift change.

A: Attention	S: Senses	P: Perception	D: Decision Making	M: Memory	C: Control	F: Feedback	O: Others

Table 6.2 Task Analysis of the Shift Change Process

TASK DESCRIPTION	Task Analysis A	S	P	D	M	C	F	O	OBSERVATIONS
2.0 Shift Supervisor reviews work status at the end of shift									
2.1 Shift-Supervisor A reviews work status									
2.1.1 Shift-Supervisor A accesses job status information	*	*						*	Shift-supervisor reviews status of jobs: - completed, in-process, delayed, criticality, number of hours job in service
2.1.2 Shift-Supervisor A reviews job status information		*	*	*					
2.1.3 Shift-Supervisor A understands job status information	*	*	*	*					
2.1.4 Shift-Supervisor A accesses personnel status information	*	*							Shift-Supervisor reviews status of personnel: availability, qualification, number of hours spent on job, absenteeism, injury
2.1.5 Shift-Supervisor A reviews personnel status information	*	*	*	*					
2.1.6 Shift-Supervisor A understands personnel status information	*	*		*	*				
2.2 Shift-Supervisor A discusses completed work with individual inspector									

2.2.1 Shift-Supervisor A meets with Inspector	*							*	The meeting doesn have any fixed location or protocol (informal)
2.2.2 Shift-Supervisor A receives completed work information			*				*		Often Shift Supervisor picks up completed NRC and WC from work center and reviews information
2.2.3 Shift-Supervisor A reads completed work information	*	*	*						
2.2.4 Shift-Supervisor A understands completed work information	*	*	*	*	*				
2.3 Shift-Supervisor A completes appropriate shift status information using company system									
2.3.1 Shift-Supervisor A accesses company system	*	*						*	Shift Supervisor completes information on job and personnel using company system
2.3.2 Shift-Supervisor A completes information on current shift	*	*	*	*	*			*	
2.4 Shift-Supervisor A discusses work status with Shift-Supervisor B									
2.4.1 Shift-Supervisor A meets Shift-Supervisor B								*	The meeting takes place in the offices of the hangar floor
2.4.2 Shift-Supervisor A reviews job status information with Shift-Supervisor B	*	*	*	*	*		*		
2.4.3 Shift-Supervisor B understands job status information	*	*	*	*	*		*		Shift-supervisor A briefs Shift Supervisor B on status of work completed, WIP, delayed job, job criticality, reasons for delay
2.4.4 Shift-Supervisor A reviews personnel status information with Shift-Supervisor B	*	*	*	*	*		*		
2.4.5 Shift-Supervisor B understands personnel status information	*	*	*	*	*		*		

	S: Senses	P: Perception	D: Decision Making	M: Memory	C: Control	F: Feedback	O: Others

A: Attention							

Table 6.3 Task Analysis of the Shift Change Process

Task Description	Task Analysis A	S	P	D	M	C	F	O	Observations
3.0 Shift Supervisor B reviews work status.									
3.1 Shift-Supervisor B discusses work status with Shift-Supervisor A									
3.1.1 Shift-Supervisor B meets Shift-Supervisor A	*							*	The meeting takes place in the offices of the hanger floor
3.1.2 Shift-Supervisor B reviews job status with Forman A	*	*	*	*	*		*		
3.1.3 Shift-Supervisor B understands job status information	*	*	*	*	*		*		Shift-supervisor A briefs Shift Supervisor B on status of work completed, WIP, delayed job, job criticality, reasons for delay
3.1.4 Shift-Supervisor B reviews personnel status information with Shift-Supervisor A	*	*	*	*	*		*		
3.1.5 Shift-Supervisor B understands personnel status information	*	*	*	*	*		*		
3.2 Shift-Supervisor B reviews work status									
3.2.1 Shift-Supervisor B accesses job status information	*	*						*	Shift-supervisor reviews status of jobs: completed, in-delayed, criticality, number of hours job in service

3.2.2 Shift-Supervisor B reviews job status information	*	*	*	*					
3.2.3 Shift-Supervisor B understands job status information	*	*	*	*	*				
3.2.4 Shift-Supervisor B accesses personnel status information	*	*							Shift-Supervisor reviews status of personnel: availability, qualification, number of hours spent on job, absenteeism, injury
3.2.5 Shift-Supervisor B reviews personnel status information	*	*	*	*					
3.2.6 Shift-Supervisor B understands personnel status information.	*	*	*	*	*				
3.3 Shift-Supervisor B completes appropriate shift status information using company system									
3.3.1 Shift-Supervisor B accesses company system	*	*						*	Shift Supervisor completes information on job and personnel using company system
3.3.2 Shift-Supervisor B completes information on current shift	*	*	*	*	*			*	
3.4 Shift-Supervisor B conducts pre shift meetings									
3.4.1 Shift-Supervisor B and Inspector(s) meet at assigned place	*	*					*	*	The meeting usually takes place in a common meeting room right outside the shift supervisor's office
3.4.2 Shift-Supervisor B conducts meeting									Shift Supervisor provides a brief overall review of work to be completed.
3.4.3 Shift-Supervisor B reviews job status information	*	*		*	*	*	*		Often the meeting doesn't follow a fixed protocol. Shift supervisor conducts the shift meeting.
3.4.4 Inspector(s) understand job and personnel status									Organization do not have a clearly defined protocol as to what needs to be discussed at the

Task Description	A	S	P	D	M	C	F	O	Observations
									meeting.
3.4.5 Shift-Supervisor B assigns work to inspector(s)	*			*	*				

A: Attention	S: Senses	P: Perception	D: Decision Making	M: Memory	C: Control	F: Feedback	O: Others

Table 6.4 Task Analysis of the Shift Change Process

Task Description	Task Analysis								Observations
	A	S	P	D	M	C	F	O	
4.0 Inspector B commences work at the beginning of the shift B									
4.1 Inspector B receives work from Shift-Supervisor B									
4.1.1 Shift-Supervisor B assigns work to Inspector B	*			*	*				Based on his/her qualification, Shift-Supervisor B – assigns work from the list of available work.
4.1.2 Inspector B receives work from Shift-Supervisor B	*						*		No job aid available to assist shift supervisor in work assignments.
4.1.3 Inspector B understands work instructions	*	*	*	*	*		*		Has to develop skills of work delegation and use knowledge and past experience.
4.2 Inspector B picks up the work card from the work center	*							*	
4.3 Inspector B reviews work card information.									Inspector B also

4.3.1 Inspector understands work card instructions.	*	*	*	*	*	*	reviews WIP information
4.4 Inspector B discusses work-status with inspector A.							
4.4.1 Inspector B discusses written information on WIP with Inspector A							Inspectors have a face communication (typically done for WIP). Often this may not happen because of lack of time, poor scheduling, on part of inspector(s), overconfidence and non adherence to company procedures
4.4.2 Inspector B gets debriefed from Inspector A at inspection site on ongoing work							Inspectors may not have access to site because of parallel work or difficult to reach areas.
4.5 Inspector B understand ongoing work							
4.6 Inspector B commences work **							

** Activity not analyzed as part of shift change.							
A: Attention	S: Senses	P: Perception	D: Decision Making	M: Memory	C: Control	F: Feedback	O: Others

6.3 HUMAN ERROR IN SHIFT CHANGE – DEVELOPMENT OF A TAXONOMY

The error taxonomy development was a two-step process. Initially, the Failure Effects Modes Analysis (FEMA) Approach was applied to develop the taxonomy of errors as shown in Tables 6.5 through 6.8. Following this step, Rouse and Rouse's 10 behavioral framework was used to classify errors during a shift change process. This error framework, which classifies human errors based on causes as well as contributing factors and events, has been employed to record and analyze human errors in several contexts such as detection and diagnostics, trouble-shooting and aircraft mission flights. The scheme is detailed below:

Human Error Cause

Human errors are attributed to one or more of the following:

1. Inherent human limitations

These may be related to levels of training and experience, and attitudinal factors such as interpersonal relationships, complacency, or overconfidence in automated components.

2. Inherent system limitations

In the context of this study, these may include the design of procedures and operating instructions, and the utility and ease-of-use of support tools to carry out the required tasks.

3. Contributing conditions

These may include features of the working environment such as noise, poor visibility, or excessive workload.

4. Contributing events

These may include distractions, poor communication between personnel, and equipment failure of, for example, maintenance tools.

Table 6.5 Error Taxonomy (1)

TASK	ERRORS	OUTCOME
1. Inspector A completes assigned work on shift A		
1.1 Inspector A completes inspection (portions or complete area) **		
1.2 Inspector A enters information on status of work completed	E1.2.1 Inspector A enters incorrect information E1.2.2 Inspector A enters incomplete information E1.2.3 Inspector A does not enter any information	Inspector A enters correct and complete information of work completed.
1.3 Inspector A enters information using system for work in progress (WIP)	E1.3.1 Inspector A enters incorrect information E1.3.2 Inspector A enters incomplete information E1.3.3 Inspector A does not enter any information	Inspector A enters correct and complete information for work in progress (WIP)
1.4 Inspector A returns to work center on completion of work	E1.4.1 Inspector A does not return to work center on completion of work	Inspector A returns to work center
1.5 Inspector A returns cards to location in the work center	E1.5.1 Inspector A does not return work card E1.5.2 Inspector A places card in incorrect location	Inspector A returns cards to correct location in the work center
1.6 Inspector A enters status of tools and equipment borrowed	E1.6.1 Inspector A does not complete information on tools and equipment status E1.6.2 Inspector A provides incomplete information on	Inspector A correctly enters the status of tools

	tools and equipment status	
1.7 Inspector A returns borrowed tools and equipment	E1.7.1 Inspector A fails to return borrowed tools and equipment. E1.7.2 Inspector A return only a partial list of tools and equipment	Inspector A returns borrowed tools and equipment
1.8 Inspector A briefs shift supervisor on work status	E1.8.1 Inspector A doesn't debrief shift supervisor on work status. E1.8.2 Inspector A provides a partial debrief shift supervisor on work status	Inspector A correctly briefs shift supervisor on work status
1.9 Inspector A briefs inspector B on work status		
1.9.1 Inspector A discusses written information on WIP with inspector B	E1.9.1.1 Inspector A doesn't debrief Inspector B on written information of work status E1.9.1.2 Inspector A provides partial information on WIP E1.9.1.3 Inspector A provides incorrect information	Inspector A provides correct and complete information on shift work
1.9.2 Inspector A debriefs Inspector B at inspection site on work in progress (WIP)	E1.9.2.1 Inspector A not available to go to worksite for work in progress (WIP) E1.9.2.2 Inspector B not available to go to worksite for WIP E1.9.2.3 Inspector A and B not available to go to work-site E1.9.2.4 Access to site not possible E1.9.2.5 Incomplete oral communication on WIP E1.9.2.6 Incorrect oral communication on WIP	Inspector A debriefs inspector B correctly and completely on WIP

** Activity not analyzed as part of shift change.

Table 6.6 Error Taxonomy (2)

TASK	ERRORS	OUTCOME
2 Shift A Supervisor reviews work status at the end of shift A		
2.1 Shift-Supervisor A reviews work status		
2.1.1 Shift-Supervisor A accesses job status information	E2.1.1.1 Fails to get job status information E2.1.1.2 Gets incomplete information E2.1.1.3 Gets incorrect information	Supervisor accesses correct and complete information

2.1.2 Shift-Supervisor A reviews job status information	E2.1.2.1 Job status information not available E2.1.2.2 Fails to read job status information E2.1.2.3 Partially reads job status information	Supervisor reviews correct and complete job status information
2.1.3 Shift-Supervisor A understands job status information	E2.1.3.1 Fails to understand job status information E2.1.3.2 Misinterprets job status information E2.1.3.3 Does not act on job status information	Supervisor understands correct and complete job status information
2.1.4 Shift-Supervisor A accesses personnel status information	E2.1.4.1 Fails to get personnel status information E2.1.4.2 Gets incomplete information	Supervisor accesses correct and complete personnel status information
2.1.5 Shift-Supervisor A reviews personnel status Information	E2.1.5.1 Personnel status information not available E2.1.5.2 Fails to read personnel status information E2.1.5.3 Partially reads personnel status information	Supervisor reviews correct and complete personnel status information
2.1.6 Shift-Supervisor A understands personnel status information	E2.1.6.1 Fails to understand personnel status information E2.1.6.2 Misinterprets personnel status information E2.1.6.3 Does not act on personnel status information	Supervisor understands correct and complete personnel status information
2.2 Shift-Supervisor A discusses work status with individual Inspectors		
2.2.1 Shift-Supervisor A meets with inspector	E2.2.1.1 Inspector not available E2.2.1.2 Shift-Supervisor not available E2.2.1.3 Shift-Supervisor and inspector not available	Shift-Supervisor A and inspector meet.
2.2.2 Shift-Supervisor A receives completed work information	E2.2.2.1 Fails to receive work information from inspector E2.2.2.2 Receive incomplete work status information E2.2.2.3 Receives incorrect information from Inspector	Shift-Supervisor A receives accurate and complete information of the completed work
2.2.3 Shift-Supervisor A reads completed work information	E2.2.3.1 Fails to read completed status information E2.2.3.2 Partially reads information	Shift-Supervisor A completely reads information
2.2.4 Shift-Supervisor A understands completed work information	E2.2.4.1 Fails to understand information E2.2.4.2 Misinterprets information E2.2.4.3 Does not act on information	Shift-Supervisor A correctly understands completed work information
2.3 Shift-Supervisor A completes appropriate shift		

status information using company system		
2.3.1 Shift-Supervisor A accesses company system	E2.3.1.1 Company system not available E2.3.1.2 Does not access company system	Shift-Supervisor A accesses company system accurately
2.3.2 Shift-Supervisor A completes information on current shift	E2.3.2.1 Fails to complete information E2.3.2.2 Partially completes information E2.3.2.3 Incomplete information	Shift-Supervisor A completes accurate and complete information on current shift
2.4 Shift-Supervisor A discusses work status with Shift-Supervisor B		
2.4.1 Shift-Supervisor A meets Shift-Supervisor B	E2.4.1.1 Shift-Supervisor A is not available E2.4.1.2 Shift-Supervisor B is not available E2.4.1.3 Shift-Supervisor A and B are not available	Shift-Supervisor A meets Shift-Supervisor B successfully
2.4.2 Shift-Supervisor A reviews job status information with Shift-Supervisor B	E2.4.2.1 Shift-Supervisor A does not provide job status information E2.4.2.2 Shift-Supervisor A provides incomplete job status information E2.4.2.3 Shift-Supervisor A provides incorrect job status information	Shift-Supervisor A reviews accurate and complete job status information with Shift Supervisor B
2.4.3 Shift-Supervisor B understands job status information	E2.4.3.1 Shift-Supervisor B fails to understand job status information E2.4.3.2 Shift-Supervisor B misinterprets job status information E2.4.3.3 Shift-Supervisor B does not act on job status information	Shift-Supervisor B understands correct job status information
2.4.4 Shift-Supervisor A reviews personnel status	E2.4.4.1 Shift-Supervisor A does not provide personnel status information E2.4.4.2 Shift-Supervisor A provides incomplete personnel status information E2.4.4.3 Shift-Supervisor A provides incorrect personnel status information	Shift-Supervisor A reviews accurate and complete personnel status information
2.4.5 Shift-Supervisor B understands personnel status information	E2.4.5.1 Fails to understand personnel status information E2.4.5.2 Misinterprets personnel status information E2.4.5.3 Does not act on personnel status information	Shift-Supervisor B correctly understands personnel status information

Table 6.7 Error Taxonomy (3)

TASK	ERRORS	OUTCOME

3.0 Shift-Supervisor /Shift Supervisor reviews work status

3.1 Shift-Supervisor B discusses work status with Shift-Supervisor A

3.1.1 Shift-Supervisor B meets Shift-Supervisor A	E3.1.1.1 Shift-Supervisor A is not available	Shift-Supervisor B meets Shift-Supervisor A
	E3.1.1.2 Shift-Supervisor B is not available	
	E3.1.1.3 Shift-Supervisor A and B are not available	
3.1.2 Shift-Supervisor B reviews job status	E3.1.2.1 Shift-Supervisor B does not provide job status information	Shift-Supervisor B reviews job status accurately and completely
	E3.1.2.2 Shift-Supervisor B provides incomplete job status information	
	E3.1.2.3 Shift-Supervisor B provides incorrect job status information	
3.1.3 Shift-Supervisor B understands job status information	E3.1.3.1 Shift-Supervisor B fails to understand job status information	Shift-Supervisor B correctly understands job status information
	E3.1.3.2 Shift-Supervisor B misinterprets job status information	
	E3.1.3.3 Shift-Supervisor B does not act on job status information	
3.1.4 Shift-Supervisor B reviews personnel status information	E3.1.4.1 Shift-Supervisor B does not provide personnel status information	Shift-Supervisor A reviews correct and complete personne status information
	E3.1.4.2 Shift-Supervisor B provides incomplete personnel status information	
	E3.1.4.3 Shift-Supervisor B provides incorrect personnel status information	
3.1.5 Shift-Supervisor B understands personnel status information	E3.1.5.1 Shift-Supervisor B fails to understand personnel status information	Shift-Supervisor A correctly understands personnel status information
	E3.1.5.2 Shift-Supervisor B misinterprets personnel status information	
	E3.1.5.3 Shift-Supervisor B does not act on personnel status information	

3.2 Shift-Supervisor B reviews work status

3.2.1 Shift-Supervisor B accesses job status information	E3.2.1.1 Fails to get job status information E3.2.1.2 Gets incomplete information	Shift-Supervisor B accesses correct and complete job status information
3.2.2 Shift-Supervisor B reviews job status information	E3.2.2.1 Job status information not available E3.2.2.2 Fails to read job status information E3.2.2.3 Partially reads job status information	Shift-Supervisor B reviews job status accurately and completely
3.2.3 Shift-Supervisor B understands job status information.	E3.2.3.1 Fails to understand job status information E3.2.3.2 Misinterprets job status information E3.2.3.3 Does not act on job status information	Shift-Supervisor B correctly understands job status information
3.2.4 Shift-Supervisor B accesses personnel status information	E3.2.4.1 Fails to get personnel status information E3.2.4.2 Gets incomplete information	Shift-Supervisor B accesses correct and complete personnel status information
3.2.5 Shift-Supervisor B reviews personnel status information	E3.2.5.1 Personnel status information not available E3.2.5.2 Fails to read personnel status information E3.2.5.3 Partially reads personnel status information	Shift-Supervisor B reviews accurate and correct personnel status information
3.2.6 Shift-Supervisor B understands personnel status information	E3.2.6.1 Fails to understand personnel status information E3.2.6.2 Misinterprets personnel status information E3.2.6.3 Does not act on personnel status information	Shift-Supervisor B correctly understands job status information

3.3 Shift-Supervisor B completes appropriate information using

company system

3.3.1 Shift-Supervisor B accesses company system	E3.3.1.1 Company system not available	Shift-Supervisor B accesses accurate company system
	E3.3.1.2 Does not access company system	
3.3.2 Shift-Supervisor B completes information on current shift	E3.3.2.1 Fails to complete information	Shift-Supervisor B completes accurate and complete information on current shift
	E3.3.2.2 Partially completes information	
	E3.3.2.3 Incomplete information	
3.4 Shift-Supervisor B conducts pre shift meetings		
3.4.1 Shift-Supervisor and inspector(s) meet at assigned place	E3.4.1.1 No formal assigned shift meeting place	Shift-Supervisor and inspector meet at assigned place
	E3.4.1.2 No assigned meeting times	
	E3.4.1.3 Inspector not available for shift meeting	
	E3.4.1.4 Shift-Supervisor not available for shift meeting	
	E3.4.1.5 Inspector and Shift-Supervisor not available for shift meeting	
3.4.2 Shift-Supervisor conducts meeting	E3.4.2.1 No assigned meeting protocol	Shift-Supervisor conducts meeting properly
	E3.4.2.2 Does not follow meeting protocol	
3.4.3 Shift-Supervisor provides work status information (job and personnel)	E3.4.3.1 Shift-Supervisor B does not provide work status information.	Shift-Supervisor provides job status information
	E3.4.3.2 Shift-Supervisor B provides incomplete work status information.	
3.4.4 Inspector(s) understand job and personnel status	E3.4.4.1 Inspector(s) fails to understand instructions	Inspector(s) understand job and personnel status correctly completely
	E3.4.4.2 Misinterprets work status instructions	
	E3.4.4.3 Does not act on instructions.	

3.4.5 Shift-Supervisor assigns work to inspector(s)	E3.4.5.1 Incorrect assignment	Shift-Supervisor correctly assigns work to inspector(s)
	E3.4.5.2 Not qualified for assigned work	
	E3.4.5.3 No assignment	

Table 6.8 Error Taxonomy (4)

TASK	ERRORS	OUTCOME
4.0 Inspector B commences work at the beginning of shift B		
4.1 Inspector B receives work from Shift-Supervisor B		
4.1.1 Inspector B receives work from Shift-Supervisor B	E4.1.1.1 Inspector doesn't attend shift meeting	Inspector receives work from shift-supervisor B
	E4.1.1.2 Shift-Supervisor doesn't attend shift meeting	
	E4.1.1.3 Inspector and Shift-Supervisor don't attend shift meeting	
4.1.2 Shift-Supervisor B assigns work to inspector B	E4.1.2.1 No assignment is done	Shift-Supervisor B does correct assignment of work
	E4.1.2.2 Incorrect assignment	
	E4.1.2.3 Inspector not qualified for assigned work	
4.1.3 Inspector B understands work instructions	E4.1.3.1 Inspector fails to understand instructions	Inspector B understands work instructions
	E4.1.3.2 Misinterprets instructions	
	E4.1.3.3 Does not act as per the instructions	
4.2 Inspector B picks up the work card from the work center	E4.2.1 Fails to pick up the work card	Inspector B picks up the work card from the work center

4.3 Inspector B reviews work card information	E4.3.1 Fails to review work card information	
	E4.3.2 Incorrect review	
4.3.1 Inspector understands work card instructions	E4.3.1.1 Fails to understand instructions	Inspector correctly and completely understands work card instructions
	E4.3.1.2 Misinterprets instructions	
	E4.3.1.3 Does not act on instructions	
4.4 Inspector B discusses work-status with inspector A		
4.4.1 Inspector B discusses written information on WIP with inspector A	4.4.1.1 Inspector A doesn't debrief Inspector B on written information of work status.	Inspector A provides correct and complete information on in progress
	4.41.2 Inspector A provides partial information on WIP	
	4.41.3 Inspector A provides incorrect information	
4.4.2 Inspector B gets debriefed from inspector A at inspection site	4.4.2.1 Inspector A not available to go to work-site for WIP	Inspector B gets debriefed from inspector A at inspection
	4.4.2.2 Inspector B not available to go to work-site for WIP	
	4.4.2.3 Inspector A and B not available to go to work-site	
	4.4.2.4 Access to site not possible	
	4.4.2.5 Incomplete oral communication on WIP	
	4.4.2.6 Incorrect oral communication on WIP	
4.5 Inspector B understands WIP	4.5.1 Fails to understand WIP status information	Inspector B correctly understands WIP
	4.5.2 Misinterprets ongoing work status information	
4.6 Inspector B commences work on shift B **		

** Activity not analyzed as part of shift change.

Human Error Classification

Human errors were classified based on the scheme shown in Table 6.9. Initially, the human action was assigned to the error. Following this step, all modes of error corresponding to the error classification were considered. Based on the level of detail, human actions can fall into one of the six classes described under column 1 in Table 6.9. Once the human activity is assigned an error classification, the potential for each error mode under the classification was considered. The information for the appropriate error mode was gleaned from the task analysis. Rouse's[20] approach was applied to the entire shift change operation. By way of example, the illustration for a single operation is described below.

Task: 1.2 Inspector A completes written information on work completed

On completion of an assigned activity, the inspector indicates the status of the work completed during the shift. This information is then conveyed to the foreman of the shift. If the entire work is completed, the relieved inspector returns the work-instruction card to the workstation. For incomplete work/work in progress, the relieved inspector signs for the sub-tasks completed. For partially completed sub-tasks, the inspector provides a brief description of the work accomplished and signs-off on the work completed, returning the work instruction card to the workstation. For work in progress or work delayed, the inspector also provides information on reasons for the delay, for example, non-availability of clean-up crew, awaiting equipment.

The human actions required at this stage fall into the following error classifications:

Choice of procedure: The inspector should follow correct step-by-step procedures as outlined in the company shift change procedures guide following completion of work. Based on the status of the work, there might be several options available for the inspector from which the correct one should be selected.

Execution of procedure: Once inspectors have selected the appropriate procedure, they are responsible for ensuring that the procedure has been executed correctly.

Under the choice of procedure, consideration was given to the following error modes:

Incomplete -- The inspector does not complete all the written information and does not provide the complete status on the work completed.

Incorrect – The inspector enters incorrect information pertaining to the status of the work completed.

Unnecessary --- The inspector provides non-useful information that is not relevant to the next task.

Lack – The inspector does not know what information to complete.

Under the execution of procedure, the following error modes were considered:

Omitted --- The inspector may fail to enter information corresponding to one or more items on the work card or the non-routine card.

Repeated --- Repetition of information will not directly have an impact on the task if the repeated step is executed correctly.

Added --- Inspector adds information that is not necessary to perform the task on the next shift.

Sequence --- Inspector may write steps in the wrong order (e.g., may not mention the sequence of signoffs of a buy-back inspection item)

Timing --- Inspector may not complete the work-card information before the designated time.

Incomplete – Inspector does not complete all the necessary and essential written information.

Unrelated --- Inspectors may enter information on the non-routine card that is not relevant to their assigned tasks.

Table 6.9 Error Classification Scheme (Rouse and Rouse, 1983)

Error Classification	**Error Mode**	**Brief Definition**
Observation of System State	Excessive	Improper rechecking of correct readings of appropriate state variables.
	Misinterpreted	Erroneous interpretation of correct readings of appropriate state variables.

	Incorrect	Incorrect readings of appropriate state variable.
	Incomplete	Failure to observe sufficient number of appropriate state variables
	Inappropriate	Observation of inappropriate state variables.
	Lack	Failure to observe any state variable.
Choice of Hypothesis	Inconsistent	Could not cause the particular values of state variables observed.
	Unlikely	Could cause the values observed but much more likely causes should be considered first.
	Costly	Could cause the values observed but very costly (in time or money) place to start.
	Irrelevant	Does not functionally relate to state variables observed.
Testing of hypothesis	Incomplete	Stopped before reaching a conclusion.
	Acceptance	Reached wrong conclusion.
	Rejection	Considered and discarded correct conclusions.
	Lack	Goal not chosen.
Choice of goal	Incomplete	Insufficient specification of goal.
	Incorrect	Choice of counter-productive goal.
	Unnecessary	Choice of non-productive goal.
	Lack	Goal not chosen.
Choice of procedure	Incomplete	Choice would not fully achieve goal.
	Incorrect	Choice would achieve incorrect goal.
	Unnecessary	Choice unnecessary for achieving goal.
	Lack	Procedure not chosen.
Execution of procedure	Omitted	Required step omitted.
	Repeated	Unnecessary repetition of required step.
	Added	Unnecessary step added.
	Sequence	Required steps executed in wrong order.
	Timing	Step executed too early or too late.
	Discrete	Discrete control in wrong position.
	Continuous	Continuous control in unacceptable range.
	Incomplete	Stopped before procedure complete.

	Unrelated	Unrelated inappropriate step executed.

6.4 OBSERVATIONS AND DISCUSSIONS

Following observations and discussions with various shift teams and a detailed task analysis of the shift change processes, the following general observations were made about the shift hand-over procedures between an outgoing and an incoming shift. These observations were in addition to those identified using the error taxonomy.

6.4.1 Observations:

1. Shift Protocol Related Issues:

In general, the shift hand-over procedures did not follow any defined protocol. The procedures were informal and often ad hoc. The discussions relied primarily, and in some cases heavily, on oral communication. The level of detail and discussion was dependent on the inspectors, maintenance technicians, and supervisors. Although companies have outlined basic shift change procedures, these often were not strictly adhered to. Moreover, these procedures are often difficult to locate. Detailed procedures need to be developed for situations where continuing work is transferred from one shift to the next: for example, when

--work is started on one shift but has to be stopped and continued on the next one because of various circumstances such as personnel availability, non-availability of parts or equipment, parallel work, reassignment of work

--work is started but partially completed with some items completed but not signed off

--work is started and partially completed with all completed items signed off

Meeting Location: The task meetings between inspectors and technicians often did not take place in designated areas. Meetings would often be held in a noisy environment with parallel work in progress, causing distractions.

Meeting Times: Meeting times would vary based on the task and individuals involved in the meeting.

Shift Meetings: Shift meetings and face-to-face meetings between personnel often did not follow specific protocol. They often included non-technical information not associated with work. Moreover, the level of detail and the content of the meetings varied based on the personnel conducting the meeting. The approach to shift change differed between shift supervisors. In addition, they had no formal training and guidance in what did and did not constitute a good shift hand-over.

2. Awareness and Enforcement Related Issues

Discussion with personnel revealed that they were not aware and consistent in reporting the company's written procedures on shift hand-over, although all emphasized the importance of a proper shift hand-over. It should be mentioned that all personnel we interviewed were open, sincere, and genuinely interested in assisting the research team. Although personnel were aware of the need for face-to-face debriefings during shift change, often these were not adhered to. Moreover, the nature of the debriefing between individual personnel at work sites for work-in-progress was left to individual personnel. Thus, there existed a large variability in shift change protocol based on:

- the level of detail discussed
- the quality and relevance of the discussion to the task at hand

3. Information Related Issues

Transference of work information (written communication): Written communication on work in progress is not standardized. Personnel provide different levels of detail on work completed and work in progress. There exists a need for an efficient and effective system that will facilitate the transfer of information on work in progress from one shift to the next. Often personnel have to retrieve written information on work in progress from various sources and access an involved/complicated/complex route of procedures.

Transference of other information (Material, Tool and Equipment and Personnel Information): Systems to transfer information from one shift to the next are not well developed in some cases. Moreover, several problems in accessing necessary information were identified. For example, status information on tools borrowed and returned was not easily available, and personnel had to rely on jotted notes recorded in a diary.

4. Training

Shift change training on the use of correct shift change procedures and the importance of following correct protocol is not a part of regular training at most facilities. The lack of training on shift change procedures could be because of the following reasons:

Lack of a well-developed shift change protocol,

Lack of support staff to conduct training,

Lack of management commitment emphasizing the importance of shift change in promoting safety, and

Lack of detailed guidelines and an industry-wide accepted standard for shift change.

5. Organizational Support

A critical component missing was the lack of management support for a standardized shift change protocol. In the absence of an industry-wide standard, organizations have developed their own standards. Moreover, enforcement by management of the existing shift change protocol was often found to be lacking. The protocol was not communicated to various personnel involved in shift change. In the absence of such communication, individuals had developed their own internal procedures. Thus, there exists much variability in the way shift change was accomplished.

6. MRM Related Issues

Following discussions and analysis, it was clear that personnel need training on MRM-related issues such as communication, interpersonal relationships, leadership, and decision-making. These skills are critical for facilitating a smooth shift change, but most organizations do not have programs in place to train personnel on them. The links between them and efficient teamwork in the aircraft maintenance environment has been well-documented in previous FAA reports and MRM research.

7. Lack of Useful Job-Aids:

Shift change is an information intensive task that is particularly critical in ensuring that personnel conducting the task have the right information on hand. Shift change tasks can be aided through the provision of decision support tools and job aids. Often, supervisors had to rely on memory, experience and judgment to decide on work assignments, organize shift meetings, and estimate work status. Similarly, technicians had to rely on memory and experience during task debriefings and status report updates. There is potential value in assessing the role that modern information technology can play in supporting access to information.

6.5 HUMAN FACTORS INTERVENTIONS --- A STANDARDIZED SHIFT CHANGE PROTOCOL

The error taxonomy was analyzed using a systems approach espoused by Drury3 which not only considers the traditional interaction of the operator and the task requirements but also includes operator interactions with equipment, documentation, and other personnel within the constraints imposed by the system. Table 6.10 – 6.13 lists the errors and identifies error-causing factors based on this systems approach. Following this analysis, specific interventions to prevent shift change errors were considered with the objective of identifying specific interventions leading to an error-tolerant system and to the development of a standardized shift change process.

1. Shift Change Protocol

Analysis of the shift change operations clearly indicated the need for a detailed protocol for work transfer. The development of such a protocol will ultimately lead to a standardized shift change process that will serve as a benchmark for the industry. In order to provide the industry with guidelines, this research has outlined the critical elements for such a protocol. A flowchart for the shift change protocol is provided in Figure 6.7, and a detailed description of the critical elements follow. Individual organization can take the basic tenets of this protocol and implement it to suit their organizational and operational settings.

Protocol for Work Transfer Conducted at the End of the Shift

The following is a suggested generic protocol for transfer of work during shift change. The protocol with modification can be used by inspectors, mechanics, line maintenance, and component shops.

For work started and completed on one shift with all items signed off, personnel should

1. Complete the appropriate work card (WC)/task information.
2. Stamp and return the WC to work center.
3. Enter status of tools and equipment borrowed
4. Return tools and equipment to stores
5. Report status of work to shift supervisor.

For work started on one shift and partially completed before the end of shift with some items completed and some incomplete, personnel should

1. Complete work card and sign off on items completed.
2. Enter status of partially completed items, those for which work has been started but not signed off, using the shift change status report.(see Table 6.14)
3. Enter status of tools and equipment borrowed and their locations.
5. Report status of work to the shift supervisor.

For work started on one shift and stopped before the end of shift, personnel should

1. Complete work card information for items completed.
2. Enter status on partially started items using the shift status report and indicate reasons for work stoppage.
3. Enter status of tools and equipment borrowed and their locations.
4. Stamp the shift status report and return WC and the shift status to the work center.

Report status of work to the shift supervisor.

Protocol for Shift Status Report (Written Communication)

In addition to completing the work card and non-routine cards (for inspectors), it is critical that all personnel, both inspectors and mechanics, involved in shift change complete a written shift status report for continuing work. A blank shift change status report form indicating the different elements is shown in Table 6.14. This report solicits information on (1) Work Status – items partially completed but not signed off, items completed but awaiting approval (e.g., a mechanic fixes a part but the inspector needs to conduct **a** buy-back inspection to ensure that it meets specifications), reasons for delay, and critical items; (2) Equipment and Tools – status and location and (3) General Comments. On completion of the shift status report, personnel should stamp the report.

Protocol for Shift Supervisor Debriefing (Oral Communication)

In preparation for the debriefing meeting, the shift supervisor coordinates with each personnel and receives a written update on the work status prior to the shift change. For the work completed, the supervisor reviews the completed work card returned to the work center; for the continuing work, the supervisor reviews the completed work card for the items completed and signed off and the shift status report for partially completed items.

Once personnel have filed the work card and the shift status report in the case of continuing work, shift supervisors conduct the debriefing at a site free from distractions. They should use a checklist to solicit information to ensure consistency in information gathering.

Following this meeting the supervisor and the personnel should visit the job site to ensure that previously completed work has been appropriately signed off and the shift status report on continuing work has been correctly completed.

Protocol for Meeting Location

It is necessary to have dedicated space that is free from the distractions of both noise and parallel work to conduct meetings. In addition to these meetings, the final turnaround and debriefing on the work should take place at the work site.

Protocol for Meeting Times

It is critical that organizations allow sufficient time for conducting a proper shift change. In the case of rotating shifts, there should be a sufficient overlap between shifts--1/2 an hour for inspectors and technicians and 1 hour for shift supervisors--to ensure that the work transfer takes place properly and employees are not pressured into adopting shortcuts. In case of organizations that do not have continuous shifts, it is critical that all information on continuing work be clearly documented using the shift status report and communicated in both written and oral form to the shift supervisors.

Protocol for Shift Supervisor's Meeting

Prior to shift change, supervisors from both shifts need to meet to discuss the status of the completed and continuing work. Supervisor of Shift A (ending shift) should transfer a written status report on the work conducted during the shift to the next supervisor (Shift B). An example of a report to be completed for each aircraft is shown in Table 6.15. The report provides detailed information on the following:

Overall Status

1. Aircraft – type, location-hangar bay, type of check

2. Job Completion Times for OTD

3. Arrival Date/Time and Departure Date/Time

Job Status

1. List of jobs to be worked on a particular aircraft with estimated completion times
2. List of jobs currently being worked on a particular aircraft
3. Assignment of personnel to jobs
4. Status of jobs – completed, in progress, stopped/delayed/deferred items (indicate status of jobs at the beginning and end of shift)
5. Time and shift job started and completed
6. Estimated number of hours spent on each activity
7. Cumulative time spend on each activity
8. Reasons for delay or work stoppage
9. List of critical items – parts on order, equipment on order, tools
10. Equipment and tool status report

Personnel Report

1. Status of personnel on shift (available, absent, in-training, injured)
2. Qualification of personnel available on shift
3. Job and number of hours worked

Housekeeping

1. Clean office area
2. Clean work area
3. Safety

After completing the shift status report, the supervisor signs off on the report, ascertaining the information and transferring it to the supervisor on the next shift. In the case of a rotating shift, the supervisor orally debriefs the next supervisor on the status of the work completed. The oral debriefing should follow the format outlined in the shift status report so that all elements relevant to the work are covered. It is critical at this stage that Supervisor B seeks answers to all pertinent questions that might affect work and personnel on the new shift.

Protocol for Shift Meeting

Shift meetings should be held in designated areas that are free from distractions. Attendance at them must be mandatory for all the personnel involved. They should be conducted by the shift supervisor in a formal setting following a definite protocol, which guides their content and conduct. They should cover the following broad topics:

1. Goals to be accomplished by personnel on Shift B**,** focusing on the status of the aircraft in the hangar
2. Problems and possible critical items that can affect work
3. Work assignment
4. Question/Answer period

It is critical that shift meetings maintain a focus on purpose by describing the status of the work, the critical aspects of timely completion, and the adherence to safe work practices. It is important that the supervisor emphasizes the crews' role and performance in achieving the goal.

Protocol for Work Turnover Conducted at the Beginning of the Shift

Starting New Work

In the case of newly assigned work, Shift B personnel should conduct a review of the work card and associated information, for example the manufacturer's manual and AD's, in a designated area. Following this step, questions about assigned work should be discussed with the Shift B supervisor.

Continuing Work

In the case of continuing work, personnel from shift B should review the work status with appropriate personnel from Shift A. Work turnover should proceed as outlined below**:**

1. Initial Review: As part of this review, Shift B personnel should review all written information in a designated meeting area. This includes the work card information/associated information and the shift status report. Shift B personnel should ensure that all previously completed work has been correctly signed off.

2. Job Site Review: Upon completion of the initial review, personnel from Shift A and B should review the work at the work site. This review should include items completed and signed off, items partially completed, items not started, and information corresponding to entries in the shift status report. Once the review has been completed and Shift B personnel is satisfied that they have all the necessary information, they should stamp the shift status report.

Following the two reviews, the Shift B personnel should discuss any questions on assigned work with their supervisor.

In the case of conflicting information about the continuing work, either in the oral meeting or in the written information, personnel should discuss the work with their supervisors so that it is resolved at the supervisor-level.

Table 6.14 Shift Change Status Report

Shift Change Status Report				
Aircraft:	Aircraft Location:	Shift Time:	Date:	Prepared By:
Job Number: ______________________________			Job Description:_____________________________________	

Continuing Work					Completed Items					
Item Number (WC)	Partial Items Description	Comments	Stamp		Item Number	Completed Item Description	Comments	Stamp		

Material Status						Equipment / Tool Status		
Ordered Parts	Ordered By	Ordered Time/ Date	Comments	Stamp		List of Equipment	List of tools	Status

General Comments:	

Table 6.15 Shift Change Status Report

Supervisor's Shift Report			
Shift Time:	Shift Date:	Prepared By:	Stamp:

Overall Status				
Type of Aircraft	Location (Hangar)	Arrival Time	Departure Time	Type of check

Job Status							
Job Number	Job Description	Job Status (New / Continuing) Beginning of shift	End of shift	Number of Assigned Hours	Time Started	Time Completed	

Personnel Status							**Equipment / Tool Status**		
Personnel Name	Qualifications	Availability (A, P, T, I)	Job Number	Hours Worked on Job	Comments		List of Equipment	List of tools	Status

A: Absenteeism P: Present T: Training I: Injury		Housekeeping			General Comment
		Work Area (Time Cleaned)	Office Area (Time Cleaned)		

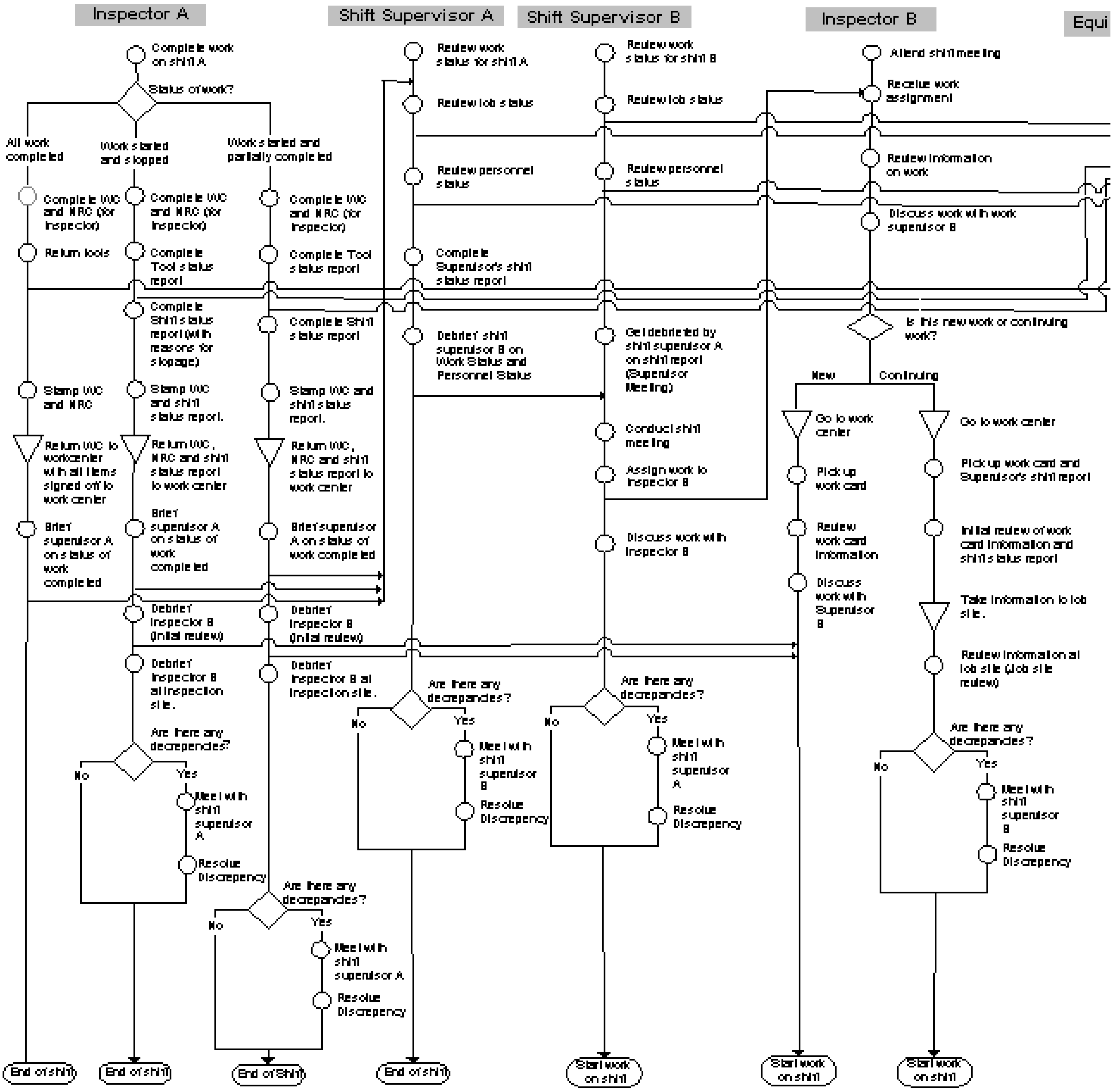

Figure 6.7 Standerdized Shift Change Protocol

2. Allocation of space and time

Analysis of the shift change operation clearly indicated that to ensure a proper shift change, organizations must provide dedicated space and time for its facilitation. Dedicated space needs to be provided to (1) conduct shift meetings, and (2) to hold personnel meetings/debriefings. The space should (1) be clean and comfortable, (2) be free from other distractions and noise, (3) be equipped with appropriate office furniture, and (4) provide access to company computer systems and other information sources. It is important that organizations provide sufficient time and overlap at the beginning and end of each shift to ensure that all personnel follow the outlined protocol.

3. Training

An obvious strategy in improving shift change performance is through training. Training for shift change can take two forms: (a) Protocol Training and (b) Team Training (also referred to as Maintenance Resource Management Training).

Protocol Training: This training should essentially focus on the correct steps to conduct a shift change so that various personnel are correctly trained in adopting the above-mentioned protocol. The essential elements of such training should focus on the following:

- The steps to be followed by various personnel to conduct a proper shift change
- The use of checklists, shift status reports, computers, data retrieval, and other job aids that support the standardized protocol.
- The communication norms (written, oral and feedback information)
- The protocol for attending and conducting meetings and debriefings
- The rules (e.g., what steps to follow in different situations, violations of procedures)**.**

Team Training: The analysis of shift change showed it to be a task requiring team work between various personnel (inspectors, technicians, supervisors, stores from one shift and the next). Gramopadhye et al.12 have identified the following skills critical to team work in the aircraft maintenance environment: communication, leadership, interpersonal relationships, and decision- making. The content of the Aircraft Maintenance Team Training (AMTT) and the Team Training software provides a good starting point for team training for all personnel involved in shift change operation.

While training for the procedural portion of the task is relatively straight-forward17, most of the opportunities for error occur in the cognitive aspects of shift change. The current state of shift change is such that very little emphasis has been paced on both protocol training and team training. Most personnel learn company shift change protocol by working with senior personnel. This type of training, while realistic, is uncontrolled. In such an environment the trainees do not get rapid, accurate feedback about the correctness of their approach. The literature on training provides guidance in designing programs to provide sufficient control. Embrey8 states that for any training program to be effective, it should address the following three issues: the attitude of the trainee at work, the knowledge required to perform the job, and the specific skills required to perform the task. Specific training methods, which can be used, for inspection training5,12are described below:

1. Pre-training: Pre-training provides the trainee with information concerning the objectives and scope of the training program. During pre-training, pretests can be used to measure (a) the level at which trainees are entering the program and (b) cognitive or perceptual abilities that can later be used to gauge training performance/progress. Advanced organizers or overviews, which are designed to provide the trainee with the basics needed to start the training program, have been found to be useful. The elaboration theory of instruction19 proposes that training should be imparted in a top-down manner wherein a general level is taught first before proceeding to specifics. Overviews can fulfill this objective by giving the trainee an introduction to the training program and facilitating assimilation of new material.

2. Feedback: A trainee needs rapid, accurate feedback in order to know whether a non-conformity was classified correctly or a search pattern was effective. Feedback with knowledge of results, coupled with some attempt of performing the task, provides a universal method of improving task performance.24 This applies to learning facts, concepts, procedures, problem solving skills, cognitive strategies, and motor skills.2,1 The training program should start with rapid feedback which should be gradually delayed until the "operational level" is reached. Providing regular feedback beyond the training session will help to keep the inspector calibrated (e.g., Drury4). Gramopadhye, Drury and Prabhu 13 classify feedback as performance and process feedback. Performance feedback on inspection typically consists of information on search times, search errors and decision errors. Process feedback, on the other hand, informs the trainee about the search process, such as areas missed. Another type of feedback called "cognitive feedback," which has emerged from the area of social judgment theory, is the information provided to the trainees of some measure of the output of their cognitive processes. For inspection tasks, process feedback is the same as cognitive feedback.

3. Active Training: In order to keep the trainee involved and to aid in internalizing the material, an active approach is preferred. In active training, the trainee makes an active response after each piece of new material is presented, e.g., identifying **a** new piece of information. Czaja and Drury3 used an active training approach and demonstrated its effectiveness for a complex task.

4. Progressive Parts Training: Salvendy and Seymour21 successfully applied progressive part training methodology to training industrial skills. In the progressive parts methodology, parts of the job are taught to criterion and then successively larger sequences of parts are taught. For example, if a task consists of four elements E1, E2, E3 and E4, they would be taught in the following manner:

- E1, E2, E3 and E4each trained separately to criterion
- E1 and E2 trained and then E3 and E4 trained to criterion
- E1, E2 and E3 trained to criterion and E2, E3 and E4 trained to criterion
- The entire task trained to criterion

This method allows the trainee to understand each element separately as well as the links between the various elements, thus representing a higher level of skill. On the other hand, reviews of literature reveal that part task training is not always superior. The choice of whether training should be part or whole task depends on the "cognitive resources" imposed by the task elements and the "level of interaction" among the individual task elements (Gordon, 1994). Thus, there could be situations in which one type of task training is more appropriate than the other. Naylor and Briggs18 have postulated that for tasks of relatively high organization or complexity, whole task training should be more efficient than part task training methods.

5. Schema Training: The trainee must be able to generalize the training to new experiences and situations because it is impossible to train personnel on every situation that may occur during a shift change. Thus, the personnel will need to develop a "schema," the correct mental model, which will allow a correct response to be made in novel situations. The key to the development of schema is to expose the trainee to controlled variability in training7

6. Feedforward Training: It is often necessary to cue the trainee as to what should be perceived. The trainee must know what to look for and where to look**.** Specific techniques within cueing include match-to-sample and delayed match-to-sample. Feedforward information can take different forms such as physical guidance, demonstrations, and verbal guidance. Feedforward should provide the trainee with clear and unambiguous information that can be translated into improved performance.

4. Environmental Changes (Organizational and Physical)

The following changes need to be implemented at the organizational level.

Organizational Commitment: In order to ensure a smooth shift change, organizational commitment to a standardized process is critical. This commitment needs to come from all levels – management, supervisory and hangar floor personnel. Only then will we see the benefits of implementing a standardized shift change protocol.

Infrastructure/Resource Support: It is critical that the personnel involved are supported with resources dedicated to conducting a shift change. These include meeting rooms, access to computers, and designated times at the start and the end of the shift. In addition, organizations need to invest in the development of training and retraining programs.

Awareness Programs: It is critical that organizations implement awareness programs that communicate the importance of shift change to all personnel. This can be accomplished through regular refresher courses, bulletins/circulars, and electronic communications. Moreover, each company and maintenance organization should have a statement of values emphasizing teamwork. These values should link with management practices with the rationale for them.

Enforcement: It is critical that organizations have systems in place to ensure strict adherence to shift change protocol. This adherence should be strictly monitored, and violations should be reported and corrected.

Physical Environment: Organizations have to ensure that the physical environment provides easy access to computers, instructional manuals, and job-aids as well as being clean and free from distractions from parallel work and noise.

5. Job Aids and Advanced Technology

The shift change operation can be tremendously aided by the use of advanced technology tools. Shift change is an information intensive task and information technology has a very important role to play in this environment. Examples of how shift change operation can be assisted through the use of technology are described below.

Form Fill-in Interfaces using hand free technology: The task of aircraft maintenance personnel can be tremendously aided by use of intelligent interfaces that rely on voice recognition system. Thus freeing the operator from the mundane task of keying in information. Also, personnel can request various information without having to key in information.

Use of Electronic Data Management/Product Data Management Systems: Over the years EDM/PDM systems have come of age that Commercial of The Shelf Software can be used to implement various EDM/PDM based solutions. The objective of these systems is to make data available to the right person at the right time. PDM/EDM systems are specifically designed to address the information demands of process industries, like maintenance. PDM systems allow for faster and more accurate updates to manuals, regulations and other written documentation, managing information transfer; improving completeness and accuracy of information entered on forms, making referenced information more readily and easily available, etc. Moreover, a recent study conducted by Millians and Gramopadhye (see Chapter 9) successfully demonstrated the improvements in performance resulting from the implementation of an EDM/PDM based solution for a specific aircraft maintenance process. They concluded that PDM solutions have the potential to improve the integrity of aircraft maintenance process and ultimately aviation safety.

Job-Aiding and Training: Specific decision support tools can be used to aid the task of supervisors (for e.g., decision support system to aid supervisors make decisions on worker assignment, managing shift meeting and allocating resources). Similarly, personnel can be trained using computers by incorporating multimedia features (using simulations, video, audio, graphics and text) and by incorporating principles of training which, we know work.

However, it should be emphasized that although computer technology provides us with tremendous potential to improve performance we should be pragmatic in its use. It should not be thought as a complete solution but be thought as complementing existing strategies to improving safety and reliability.

6.6 CONCLUSIONS

The research reported here represents the results of task analysis of shift change operations conducted at representative aircraft maintenance facilities. Although the sample size was restricted to the team partners, the results here can be generalized so that they can be used and applied by other organizations. The development of the error taxonomy followed by the identification of human factor interventions has lead to the development of a standardized shift change protocol. It is anticipated that the adoption and use of the protocol by the aviation industry will ultimately lead to a safer and more effective and efficient shift change. The following extensions to this research are envisioned by the authors. It is important that the research team and the FAA work closely with the organizations to implement and measure the effectiveness of these changes.

Protocol Implementation: It is critical to implement and test the developed protocol using industry partners at representative sites. Data obtained from this study can be used to further refine and standardize the protocol, which can serve as a benchmark for the industry.

Controlled Study: Following protocol implementation, a controlled study needs to be conducted which will evaluate the existing shift change practices in relation to the “standardized protocol.” This study should evaluate and document the effect of the standardized protocol in improving the effectiveness and efficiency of maintenance operations, the adherence to regulations, the subjective satisfaction, and in the measurement of changes in attitudinal performance.

Development of Training Programs/Dissemination: It is critical that appropriate training programs are developed that will train various personnel in adopting the protocol. Moreover, workshops need to be developed and presented at professional meetings attended by the aviation community to help disseminate the protocol to the general aviation community.

Development of Job Aids and Advanced Technology Tools: The protocol can be assisted by the use of job aids and advanced technology tools. It is critical that we develop prototype tools and demonstrate their use to the aviation industry.

Table 6.10 Error Shaping Factors and Interventions (Examples)

Errors from task analysis	Error Shaping Factors				
	Human	Task	Work Space	Equipment/Tools	Documentation
E1.2.1 Inspector A enters incorrect information	Memory slip, overconfidence, incomplete knowledge, recall error, lack of knowledge, familiar shortcut				
E1.2.2 Inspector A enters incomplete information	Memory slip, overconfidence, incomplete knowledge, recall error, lack of knowledge, familiar shortcut				
	Memory slip, overconfidence, incomplete knowledge, recall error,				Lack of procedures

E1.2.3 Inspector does not enter any information	lack of knowledge, familiar shortcut				
E1.3.1 Inspector A enters incorrect information	Memory slip, overconfidence, incomplete knowledge, recall error, lack of knowledge, familiar shortcut				Lack of procedures
E1.3.2 Inspector A enters incomplete information	Memory slip, overconfidence, incomplete knowledge, recall error, lack of knowledge, familiar shortcut				Lack of procedures
E1.3.3 Inspector does not enter any information	Memory slip, overconfidence, incomplete knowledge, recall error, lack of knowledge, familiar shortcut				
E1.4.1 Inspector A does not return to work center on completion of work	Memory slip and recall error				
E1.5.1 Inspector A does not return work card	Memory slip and recall error				
E1.5.2 Inspector A places card in incorrect location	Memory slip and frequency of use				
E1.6.1 Inspector A does not complete and information on tools and equipment status	Memory slip and recall error				Lack of system procedure No tools/ equipment documentation procedure
E1.6.2 Inspector A provides incomplete information on tools and equipment status	Memory slip and recall error, selectivity				Lack of system procedure No tools/ equipment documentation procedure
E1.7.1 Inspector A fails to return borrowed tools and equipment.	Memory slip, recall error and lack of knowledge		No designated stores area	No tool/ equipment tracking procedure	
E1.7.2 Inspector A return only a partial list of tools and equipment	Memory slip and recall error		No designated stores area	No tool/ equipment tracking procedure	
E1.8.1 Inspector A doesn't debrief shift supervisor on work status.	Memory slip, Lack / incomplete knowledge	No protocol of task debriefing			

E1.8.2 Inspector A provides a partial debrief shift supervisor on work status	Memory slip, Lack / incomplete knowledge	No protocol of task debriefing		
E1.9.1.1 Inspector A doesn't debrief Inspector B on written information of work status	Memory slip and recall error	No protocol of task debriefing		
E1.9.1.2 Inspector A provides partial information on WIP	Memory slip and recall error	No protocol of task debriefing		
E1.9.1.3 Inspector A provides incorrect information	Lack of knowledge, memory slip and recall error	No protocol of task debriefing		
E1.9.2.1 Inspector A not available to go to worksite for work in progress (WIP)	Overconfidence, Slip	No established protocol as part of task procedure	No access to work space because of parallel work	No equipment to access site
E1.9.2.2 Inspector B not available to go to worksite for WIP	Overconfidence, Slip	No established protocol as part of task procedure	No access to work space because of paralel work	No equipment to access site
E1.9.2.3 Inspector A and B not available to go to work-site	Overconfidence, Slip		No access to work space because of paralel work	No equipment to access site
E1.9.2.4 Access to site not possible			Paralled work in progress	Non availability of access equipment
E1.9.2.5 Incomplete oral communication on WIP	Poor communication skill, lack or incomplete knowledge			
E1.9.2.6 Incorrect oral communication on WIP	Poor communication skill, lack or incomplete knowledge			

Table 6.11 Error Shaping Factors and Interventions (Examples)

Errors from task analysis	Error Shaping Factors				
	Human	Task	Work Space	Equipment/Tools	Documentation

E2.1.1.1 Fails to get job status information	Overconfidence, Speed Accuracy trade-off	Access equipment not available	Status system not available
E2.1.1.2 Gets incomplete information	Overconfidence Speed Accuracy trade-off, Selectivity	Access equipment not available	Status system not available
E2.1.1.3 Gets incorrect information	Memory slip, Lack of knowledge, Recall error, Speed Accuracy trade-off	Access equipment not used properly	Status system not available
E2.1.2.1 Job status information not available		Access equipment not used properly	Status system not available
E2.1.2.2 Fails to read job status information	Memory slip, Speed Accuracy trade-off, Overconfidence		
E2.1.2.3 Partially reads job status information	Selectivity, Memory Slip		
E2.1.3.1 Fails to understand job status information	Lack of knowledge		
E2.1.3.2 Misinterprets job status information	Lack of knowledge		
E2.1.3.3 Does not act on job status information	Slip Lack of knowledge		
E2.1.4.1 Fails to get personnel status information	Memory slip, Speed Accuracy trade-off, Overconfidence		
E2.1.4.2 Gets incomplete information	Memory slip and recall error, selectivity		Lack of system procedure No tools/ equipment documentation procedure Lack of training, Loose adherence to system procedures
E2.1.5.1 Job status information not available		Access equipment not used properly	Status system not available

E2.1.5.2 Fails to read job status information	Memory slip, Speed Accuracy trade-off, Overconfidence				
E2.1.5.3 Partially reads personnel status information	Selectivity, Memory Slip				
E2.1.6.1 Fails to understand personnel status information	**Lack or incomplete knowledge**				
E2.1.6.2 Misinterprets personnel status information	**Lack or incomplete knowledge**				
E2.1.6.3 Does not act on personnel status information	**Slip** **Lack of knowledge**				
E2.2.1.1 Inspector not available	**Overconfidence,** **Slip**	**No established protocol as part of task procedure**	**No access to work space because of parallel work**	**No equipment to access site**	**No documented company procedure to access site**
E2.2.1.2 Shift-Supervisor not available	**Overconfidence,** **Slip**	**No established protocol as part of task procedure**	**No access to work space because of paralel work**	**No equipment to access site**	**Not documented company procedure to access site**
E2.2.1.3 Shift-Supervisor and inspector not available	**Overconfidence,** **Slip**		**No access to work space because of paralel work**	**No equipment to access site**	**Not documented company procedure to access site**
E2.2.2.1 Fails to receive work information from inspector	**Overconfidence,** **Speed Accuracy trade-off,** **Lack of knowledge**	**Parallel work interference**			
E2.2.2.2 Receives incomplete work status information	**Overconfidence,** **Speed Accuracy trade-off,** **Lack of knowledge,**	**Parallel work interference**			

	Selectivity		
E2.2.2.3 Receives incorrect information from Inspector	Overconfidence, Speed Accuracy trade-off, Lack of knowledge	Parallel work interference	
E2.2.3.1 Fails to read completed status information	Overconfidence, Speed Accuracy trade-off, Lack of knowledge		
E2.2.3.2 Partially reads information	Selectivity, Memory Slip		
E2.2.4.1 Fails to understand information	Lack of knowledge		
E2.2.4.2 Misinterprets information	Lack of knowledge		
E2.2.4.3 Does not act on information	Slip Lack of knowledge		
E2.3.1.1 Company system not available			Equipment not available
E2.3.1.2 Does not access company system	Overconfidence, Slip, Memory recall error	No established protocol as part of task procedure	
E2.3.2.1 Fails to complete information	Overconfidence, Slip, Memory recall error	No established protocol as part of task procedure	
E2.3.2.2 Partially completes information	Overconfidence, Slip, Memory recall error	No established protocol as part of task procedure	
E2.3.2.3 Incomplete information	Overconfidence, Slip, Memory recall error	No established protocol as part of task procedure	

E2.4.1.1 Shift-Supervisor A is not available	**Overconfidence,** **Slip**	**No established protocol as part of task procedure**	**No access to work space because of parallel work**	**No equipment to access site**	**No documented company procedure to access site**
E2.4.1.2 Shift-Supervisor B is not available	**Overconfidence,** **Slip**	**No established protocol as part of task procedure**	**No access to work space because of parallel work**	**No equipment to access site**	**Not documented company procedure to access site**
E2.4.1.3 Shift-Supervisor A and B are not available	**Overconfidence,** **Slip**		**No access to work space because of parallel work**	**No equipment to access site**	**Not documented company procedure to access site**
E2.4.2.1 Shift-Supervisor A does not provide job status information	**Overconfidence,** **Speed Accuracy trade-off,** **Lack of knowledge**	**Parallel work interference**			
E2.4.2.2 **Shift-Supervisor A provides incomplete job status information**	**Overconfidence,** **Speed Accuracy trade-off,** **Lack of knowledge,** **Selectivity**	**Parallel work interference**			
E2.4.2.3 Shift-Supervisor A provides incorrect job status information	**Overconfidence,** **Speed Accuracy trade-off,** **Lack of knowledge**	**Parallel work interference**			
E2.4.3.1 Shift-Supervisor B fails to understand job status information	**Lack of knowledge**	**Parallel work interference**			
E2.4.3.2 Shift-Supervisor B misinterprets job status information	**Lack of knowledge**	**Parallel work interference**			
E2.4.3.3 Shift-Supervisor B does not act on job status information	**Slip** **Lack of knowledge**	**Parallel work interference**			

E2.4.4.1 Shift-Supervisor A does not provide personnel status information	**Overconfidence,** **Speed Accuracy trade-off,** **Lack of knowledge**
E2.4.4.2 Shift-Supervisor A provides incomplete personnel status information	**Overconfidence,** **Speed Accuracy trade-off,** **Lack of knowledge,** **Selectivity**
E2.4.4.3 Shift-Supervisor A provides incorrect personnel status information	**Overconfidence,** **Speed Accuracy trade-off,** **Lack of knowledge**
E2.4.5.1 Fails to understand personnel status information	**Lack of knowledge**
E2.4.5.2 Misinterprets personnel status information	**Lack of knowledge**
E2.4.5.3 Does not act on personnel status information	**Slip** **Lack of knowledge**

Table 6.12 Error Shaping Factors and Interventions (Examples)

Errors from task analysis	**Error Shaping Factors**				
	Human	**Task**	**Work Space**	**Equipment/Tools**	**Documentation**
E3.1.1.1 Shift-Supervisor A is not available	Overconfidence, Slip	No established protocol as part of task procedure	No access to work space because of parallel work	No equipment to access site	No documented company procedure to access site
E3.1.1.2 Shift-Supervisor B is not available	Overconfidence, Slip	No established protocol as part of task procedure	No access to work space because of paralel work	No equipment to access site	Not documented company procedure to access site
E3.1.1.3 Shift-Supervisor A and B are not available	Overconfidence, Slip	No established protocol as part of task procedure	No access to work space because of paralel work	No equipment to access site	Not documented company procedure to access site

E3.1.2.1 Shift-Supervisor B does not provide job status information	Overconfidence, Speed Accuracy trade-off, Lack of knowledge	No established protocol as part of task procedure Parallel work interference
E3.1.2.3 Shift-Supervisor B provides incorrect job status information	Overconfidence, Speed Accuracy trade-off, Lack of knowledge	Parallel work interference
E3.1.3.1 Shift-Supervisor A fails to understand job status information	Lack of knowledge	Parallel work interference
E3.1.3.2 Shift-Supervisor A misinterprets job status information	Lack of knowledge	
E3.1.3.3 Shift-Supervisor does not act on job status information	Slip Lack of knowledge	
E3.1.4.1 Shift-Supervisor A does not provide personnel status information	Overconfidence, Speed Accuracy trade-off, Lack of knowledge	
E3.1.4.2 Shift-Supervisor A provides incomplete personnel status information	Overconfidence, Speed Accuracy trade-off, Lack of knowledge, Selectivity	
E3.1.4.3 Shift-Supervisor A provides incorrect personnel status information	Overconfidence, Speed Accuracy trade-off, Lack of knowledge	
E3.1.15.1 Shift-Supervisor B fails to understand personnel status information	Lack of knowledge	
E3.1.5.2 Shift-Supervisor B misinterprets personnel status information	Lack of knowledge	

E3.1.5.3 Shift- Supervisor B does not act on personnel status information	Slip Lack of knowledge		
E3.2.1.1 Fails to get job status information	Overconfidence, Speed Accuracy trade-off	Access equipment not available	Status system not available
E3.2.1.2 Gets incomplete information	Overconfidence Speed Accuracy trade-off, Selectivity	Access equipment not available	Status system not available
E3.2.2.1 Job status information not available	Lack of knowledge	Access equipment not used properly	Status system not available
E3.2.2.2 Fails to read job status information	Memory slip, Speed Accuracy trade-off, Overconfidence		
E3.2.2.3 Partially reads job status information	Selectivity, Memory Slip		
E3.2.3.1 Fails to understand job status information	Lack of knowledge		
E3.2.3.2 Misinterprets job status information	Lack of knowledge		
E3.2.3.3 Does not act on job status information	Slip Lack of knowledge		
E3.2.4.1 Fails to get personnel status information	Memory slip, Speed Accuracy trade-off, Overconfidence		
E3.2.4.2 Gets incomplete information	Memory slip and recall error, selectivity		Lack of system procedure No tools/ equipment documentation procedure Lack of training,

					Loose adherence to system procedures
E3.2.5.1 Personnel status information not available	Lack of knowledge			Access equipment not used properly	Status system not available
E3.2.5.2 Fails to read personnel status information	Overconfidence, Speed Accuracy trade-off, Lack of knowledge				
E3.2.5.3 Partially reads personnel status information	Selectivity, Memory Slip				
E3.2.6.1 Fails to understand personnel status information	Lack of knowledge				
E3.2.6.2 Misinterprets Personnel status information	Lack of knowledge				
E3.2.6.3 Does not act on personnel status information	Slip Lack of knowledge				
E3.3.1.1 Company system not available					
E3.3.1.2 Does not access company system	Overconfidence, Slip, Memory recall error		No established protocol as part of task procedure		
E3.3.2.1 Fails to complete information	Overconfidence, Slip, Memory recall error		No established protocol as part of task procedure		
E3.3.2.2 Partially completes information	Overconfidence, Slip, Memory recall error		No established protocol as part of task procedure		
E3.3.2.3 Incomplete information	Overconfidence, Slip, Memory recall error		No established protocol as part of task procedure		
E3.4.1.1 No formal assigned shift meeting place		No established protocol as part of task procedure			

E3.4.1.2 No assigned meeting times		No established protocol as part of task procedure			
E3.4.1.3 Inspector not available for shift meeting	Speed Accuracy trade-off, Overconfidence, Slip	No established protocol as part of task procedure			
				2	4
1E3.4.1.4 Shift-Supervisor not available for shift meeting	1Speed Accuracy trade-off, Overconfidence, Slip	No established protocol as part of task procedure	1 No access to work space because of parallel work	3 No equipment to access site	5 No documented company procedure to access site
E3.4.1.5 Inspector and Shift-Supervisor not available for shift meeting	Speed Accuracy trade-off, Overconfidence, Slip		No access to work space because of parallel work	No equipment to access site	Not documented company procedure to access site
E3.4.2.1 No assigned meeting protocol		No established protocol as part of task procedure			
E3.4.2.2 Does not follow meeting protocol		No established protocol as part of task procedure			
E3.4.3.1 Shift-Supervisor B does not provide work status information.	Overconfidence, Speed Accuracy trade-off, Lack of knowledge	Parallel work interference			
E3.4.3.2 Shift-Supervisor B provides incomplete work status information.	Overconfidence, Speed Accuracy trade-off, Lack of knowledge, Selectivity	Parallel work interference			
E3.4.4.1 Inspector fails to understand instructions	Lack of knowledge				
E3.4.4.2 Misinterprets work status instructions	Lack of knowledge				
E3.4.4.3 Does not act on instructions.	Slip				

	Lack of knowledge				
E3.4.5.1 Incorrect assignment	Lack of knowledge			Lack of system tools	
E3.4.5.2 Not qualified for assigned work	Lack of knowledge				
E3.4.5.3 No assignment	Slip				

Table 6.13 Error Shaping Factors and Interventions (Examples)

Errors from task analysis	Error Shaping Factors				
	Human	Task	Work Space	Equipment/Tools	Documentation
E4.1.1.1 Inspector doesn't attend shift meeting	Overconfidence, Speed Accuracy trade-off, Memory slip	No established protocol as part of task procedure			
E4.1.1.2 Shift-Supervisor doesn't attend shift meeting	Overconfidence, Speed Accuracy trade-off, Memory slip	No established protocol as part of task procedure			
E4.1.1.3 Inspector and Shift-Supervisor don't attend shift meeting	Overconfidence, Speed Accuracy trade-off, Memory slip	No established protocol as part of task procedure			
E4.1.2.1 No assignment is done	Memory slip				
E4.1.2.2 Incorrect Assignment	Lack of knowledge				
E4.1.2.3 Inspector not qualified for assigned work	Lack of knowledge				
E4.1.3.1 Inspector fails to understand instructions	Lack of knowledge				
E4.1.3.2 Misinterprets instructions	Lack of knowledge				

E4.1.3.3 Does not act as per the instructions	Slip Lack of knowledge				
E4.2.1 Fails to pick up the work card	Speed Accuracy trade-off, Memory slip				
E4.3.1 Fails to review work card information	Speed Accuracy trade-off Lack of knowledge				
E4.3.2 Incorrect review	Lack of knowledge				
E4.3.1.1 Fails to understand instructions	Lack of knowledge				
E4.3.1.2 Misinterprets instructions	Lack of knowledge				
E4.3.1.3 Does not act on instructions	Slip Lack of knowledge				
E4.4.1.1 Inspector A doesn't debrief Inspector B on written information of work status.	Overconfidence, Speed Accuracy trade-off, Lack of knowledge	No established protocol as part of task procedure			
E4.4.1.2 Inspector A provides partial information on ongoing work	Overconfidence, Speed Accuracy trade-off, Lack of knowledge, Selectivity	No established protocol as part of task procedure			
E4.4.1.3 Inspector A provides incorrect information	Overconfidence, Speed Accuracy trade-off, Lack of knowledge				
E4.4.2.1 Inspector A not available to go to work-site for partial work completed	Overconfidence, Slip	No established protocol as part of task procedure	No access to work space because of parallel work	No equipment to access site	No documented company procedure to access site
E4.4.2.2 Inspector B not available to go to work-site for partial work completed	Overconfidence, Slip	No established protocol as part of task procedure	No access to work space because of paralel work	No equipment to access site	Not documented company procedure to access site

E4.4.2.3 Inspector A and B not available to go to work-site	Overconfidence, Slip	No established protocol as part of task procedure	No access to work space because of paralel work	No equipment to access site	Not documented company procedure to access site
E4.4.2.4 Access to site not possible			Poor housekeeping, Parallel work		
E4.4.2.5 Incomplete oral communication of WIP work	Overconfidence, Speed Accuracy trade-off, Lack of knowledge, Selectivity				
E4.4.2.6 Incorrect oral communication of WIP work	Overconfidence, Speed Accuracy trade-off, Lack of knowledge				
E4.5.1 Fails to understand WIP status information	Lack of knowledge				
E4.5.2 Misinterprets WIP status information	Lack of knowledge				

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CHAPTER 7
STANDARDS FOR CERTIFICATION OF AVIATION MAINTENANCE TECHNICIAN TRAINING PROGRAMS USING THE AMT / AMT-T INTEGRATED CURRICULUM

Charles White
and
Michael Kroes

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

7.1 EXECUTIVE SUMMARY

Aviation maintenance training programs take great pride in delivering high quality education at a relatively low cost to the student and industry. Throughout history, the United States has been a leader in the efficiency and effectiveness of the delivery of aviation maintenance education. However, in recent years this competitive advantage is being lost. The present curriculum and certification system is no longer meeting the needs of the aviation industry. A substantial change in aviation maintenance technician education is required if the United States is to remain a world leader in aviation.

This project was conducted during a time of high employment demand for aviation maintenance technicians and growing concerns about possible future technician shortages. As a part of this project, a survey of aviation maintenance training providers was completed during the 2nd quarter of 1998. The survey results reveal that current employment opportunities cover the entire spectrum of the aviation industry. Two areas of rapid employment growth that were virtually non-existent 25 years ago are the regional airlines and the third-party repair stations. The survey also reveals that the trend of graduates successfully finding airline employment opportunities continues. Approximately two-thirds of graduates currently being employed in aviation will work on transport category aircraft or components.

Traditionally, AMT training has been more heavily focused on general aviation. Learning has been heavily hands-on with the student working individually in the performance of a task to a minimum acceptable level of 70%. It is essential that in future teaching of AMT's, concepts such as maintenance resource management, communication, teamwork, and continuous quality improvement be incorporated into the curriculum.

While the present system serves to insure that all persons seeking AMT certification have completed certain minimum standards, it stifles innovation in the education process. It only guarantees that the AMT candidate can answer a series of multiple choice questions that are available on the open market, complete with the correct answers.

Just as the curriculum and focus of the student training need to change, it is equally important that the present approach to school certification and operation be modified. The current system of certification and operation places an emphasis on the surveillance of the process and record keeping. It encourages an adherence to the status quo, and discourages innovations and the incorporation of new technology into the curriculum.

The successful operation of the AMT/AMT-T integrated curriculum is centered on the following principles:

- To continuously evaluate and modify curriculum effectiveness based on student outcome performance.
- To be responsive to continuing technological changes in industry.
- To be responsive to continuing changes and best practices relative to aircraft maintenance procedures.
- To be responsive to continuing changes and best practices relative to training and evaluation

In the questionnaire conducted as a part of this project, results clearly show that from the view of the training provider the present system is not adequately measuring program quality nor encouraging the upgrading of curriculum content. Program administrators and FAA inspectors are clearly more focused on record- keeping issues rather than meaningful program evaluation. Unfortunately, under the present system of "surveillance", an adversarial relationship often exists between the FAA inspector and school personnel. The questionnaire results reveal that making meaningful curriculum changes under the current system of certification and surveillance is unlikely to result in the curriculum changes that the industry is requesting.

The AMT/AMT-T integrated curriculum relies on a system of cooperation and continuous quality improvement. Continuous quality improvement is an on-going process aimed at understanding and improving program quality and student learning. It involves setting appropriate criteria and high standards for learning quality; systematically gathering, analyzing, and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document, explain, and improve performance. When it is integrated into an AMT training program it can effectively improve the quality of the training on an on-going basis.

The proposed certification standards, procedures and operational methods contained in this report will provide programs with the needed flexibility to meet current industry requirements, while at the same time, hold aviation maintenance technician training programs accountable for student performance.

7.2 INTRODUCTION

The role of the aircraft mechanic has changed dramatically over the past three decades. Yet for the past 32 years there has been no significant change in the curriculum or training standard for the aviation maintenance technician. Today the work of the aviation maintenance technician covers a wide range of skills and activities from simple day-to-day care and maintenance of aircraft, to modification of aircraft or systems, to the detection and repair of complex digital electronic fault. The training of aviation maintenance technicians has not kept pace with current industry requirements. Aviation maintenance technicians are still primarily taught the same subject matter with the same methods as they were thirty years ago. With the principle focus still on mastering specific tasks and manual skills. Many of these items have little relevance to the knowledge and skills required to maintain today's aircraft.

The successful implementation of the AMT/AMT-T integrated curriculum requires a focus on the students overall education vs. specific skill training. The purpose of aviation maintenance education is to provide a solid foundation of knowledge for continued future learning and career growth.

Except for situations such as on-the-job training, learners rarely train on the exact equipment and in the same environment that their real job tasks will require. The extent to which knowledge and skills acquired during their education transfer to their real job is called *transfer of training.* In aviation maintenance education it is important that basic knowledge, concepts, and system operational knowledge be conveyed in such a manner that it facilitates knowledge transfer. The important factor for such training appears to be its psychological rather than physical similarity to the real task. This enables items such as simulators, mockups, and computer based training to be successfully utilized.

Traditionally, AMT training has focused on the student working individually in the performance of a task to a minimum acceptable level of 70%. It is essential that teaching the AMT/AMT-T integrated curriculum include maintenance resource management concepts such as communication, teamwork, and continuous quality improvement.

Just as the methods and focus of the student training needs to change, it is equally important that the present approach to school certification and operation be modified. The current system of certification and operation places an emphasis on the detailed surveillance of the process and record keeping. It encourages an adherence to the status quo, and discourages innovations and the incorporation of new technology into the curriculum.

The successful operation of the AMT/AMT-T integrated curriculum is centered on the following principles:

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- To be responsive to continuing technological changes in industry,
- To be responsive to continuing changes and best practices relative to aircraft maintenance procedures.
- To be responsive to continuing changes and best practices relative to training and evaluation.

These concepts are not new, or unique to the aviation industry. They have been successfully implemented as a part of the pilot Advanced Qualification Program and total quality maintenance programs. To develop and operate a program that can meet the above goals it is essential that the focus remains on the “big picture” and student outcomes.

Currently, all to often the FAA is viewed in an adversarial role. The certification and operation of the integrated AMT/AMT-T program will require a working partnership with FAA inspectors that enable the inspector to gain an in-depth level of curriculum knowledge and evaluation methods. FAA program monitoring should more closely resemble an academic accreditation visit than a repair station audit.

These proposed certification standards, procedures and operational methods will provide programs with the needed flexibility to meet current industry requirements, while at the same time, hold aviation maintenance technician training programs accountable for student outcome performance.

7.3 SURVEY OF AVIATION MAINTENANCE TRAINING PROVIDERS

A survey of aviation maintenance training providers was completed during the 2nd quarter of 1998. The purpose of this survey was to identify which aspects of the present certification process are creating problems for the training provider or are preventing the incorporation of new curriculum content and technology into existing AMT programs. A copy of the questionnaire survey is included in Appendix C.

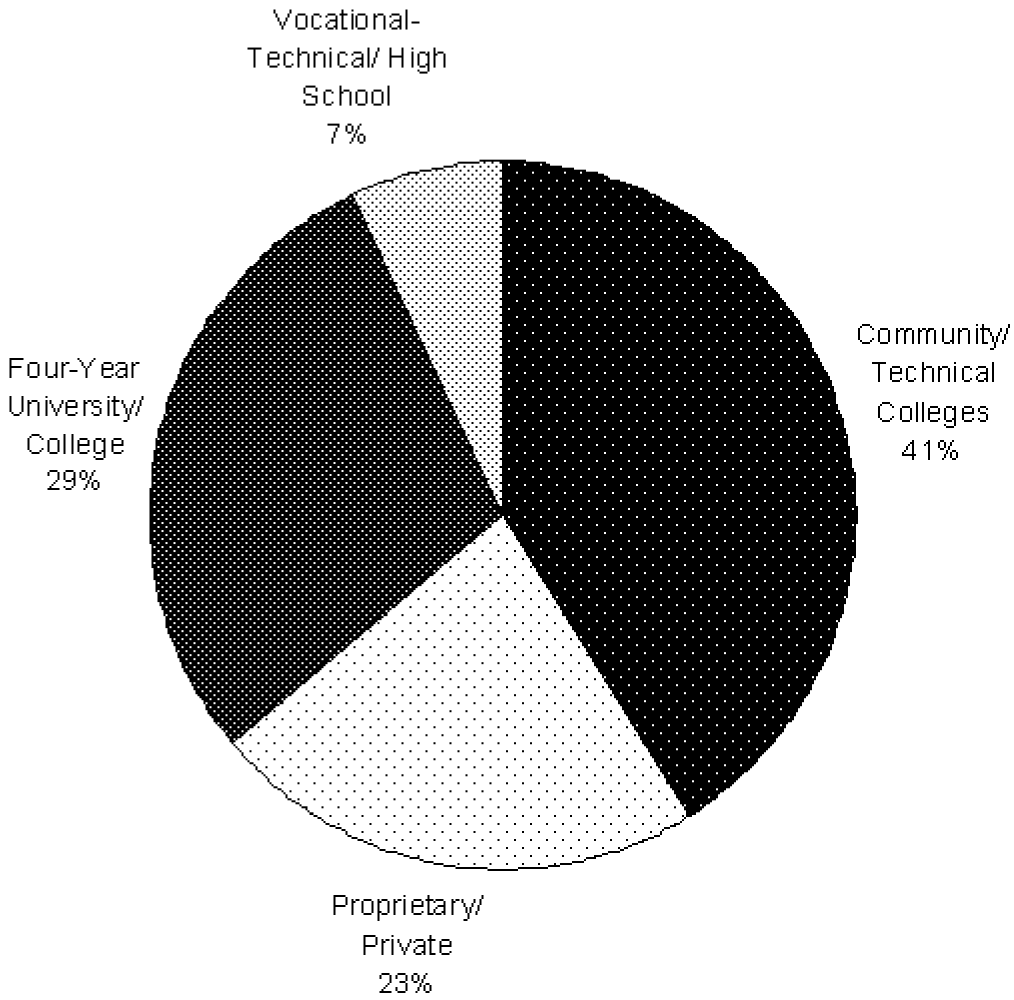

Figure 7.1 Profile of 75 Questionnaire Respondents

Survey results were obtained from 75 training providers out of a possible 186. The 75 providers from whom returns were received produce approximately 70% of graduates. These respondents provide a representative sample of the various types of programs that are currently in existence. The following chart provides information of the program types comprising the questionnaire sample.

Table 7.1 provides the results of questions 4-15.

Table 7.1 Questions 4-15

Question	Yes (%)	No (%)	Not sure (%)	No. of respondent
4. Do you believe the current system of FAA certification and surveillance adequately and fairly assesses the content and quality of your program?	26	74	-	75
5. Do you believe the current system of certification and surveillance provides flexibility for curriculum improvement and innovation?	31	69	-	75

6. Do you believe your curriculum is currently meeting industry standards?	56	44	-	75
7. Do you believe your FAA-PMI has a thorough understanding of the FAR 147 certification and surveillance procedures?	19	81	-	75
8. Have you had a consistent interpretation of certification and surveillance guidelines from your FAA inspectors?	47	53	-	75
9. Should a program advisory committee be required?	81	17	2	75
10. Should the present system of National Norms (FAA written tests) be retained?	12	88	-	75
11. Should there be a requirement for faculty development programs?	61	34	5	75
12. Should there be a standard transcript to facilitate AMT student transferability?	53	41	6	75
13. Should there be national standards(s) for entrance into AMT training programs?	29	71	-	75
14. Should the FAA sponsor regional workshops on the training standards for the AMT-T certification?	92	8	-	75
15. Should there be national standards for the approval of previous aviation training and experience (military and civilian)?	77	21	2	75

A question regarding the method of insuring quality control was asked.

16. Which would you rather see as the method for insuring AMT training program quality?

- q FAA Surveillance (present method)
- q Continuous Quality Improvement
- q Other (please list) ____

As shown in the following chart over 85% of respondents would favor a continuous quality improvement system.

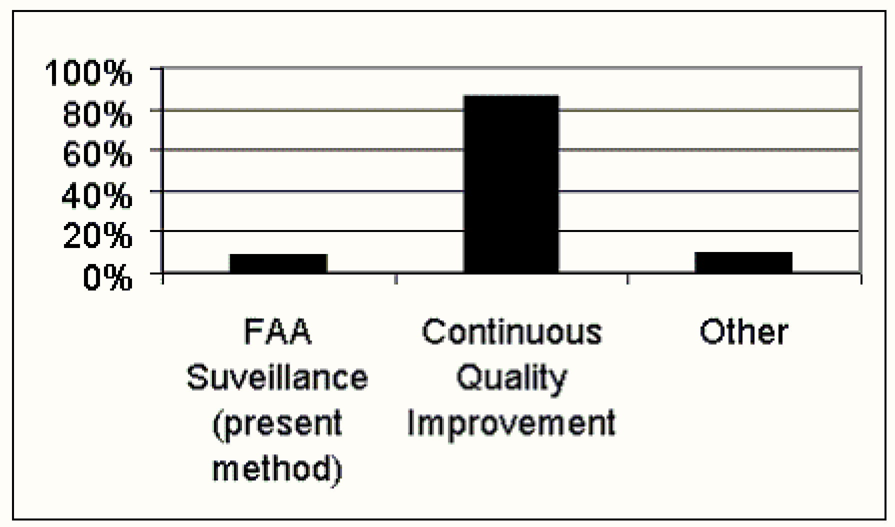

Figure 7.2 Question #16 Results

Suggestions put forward under "other" included a comprehensive national (unpublished) test, or the development of a separate accreditation body.

Question # 17 requested information on the turnover rate of FAA-PMIs being assigned to schools. The results show that in the past 5 years schools have had an average of 2.3 inspectors assigned to them. This turnover rate would mean that a school is having an inspector assigned for just slightly over 2 years. A turnover rate of this magnitude would have a sizable impact on the belief that inspectors are unfamiliar with both FAR 147 and the content and quality of a specific program.

Question # 18 asked respondents prioritize the areas causing the greatest problems in the operation of an approved FAR 147 program. The following chart provides the results of this question.

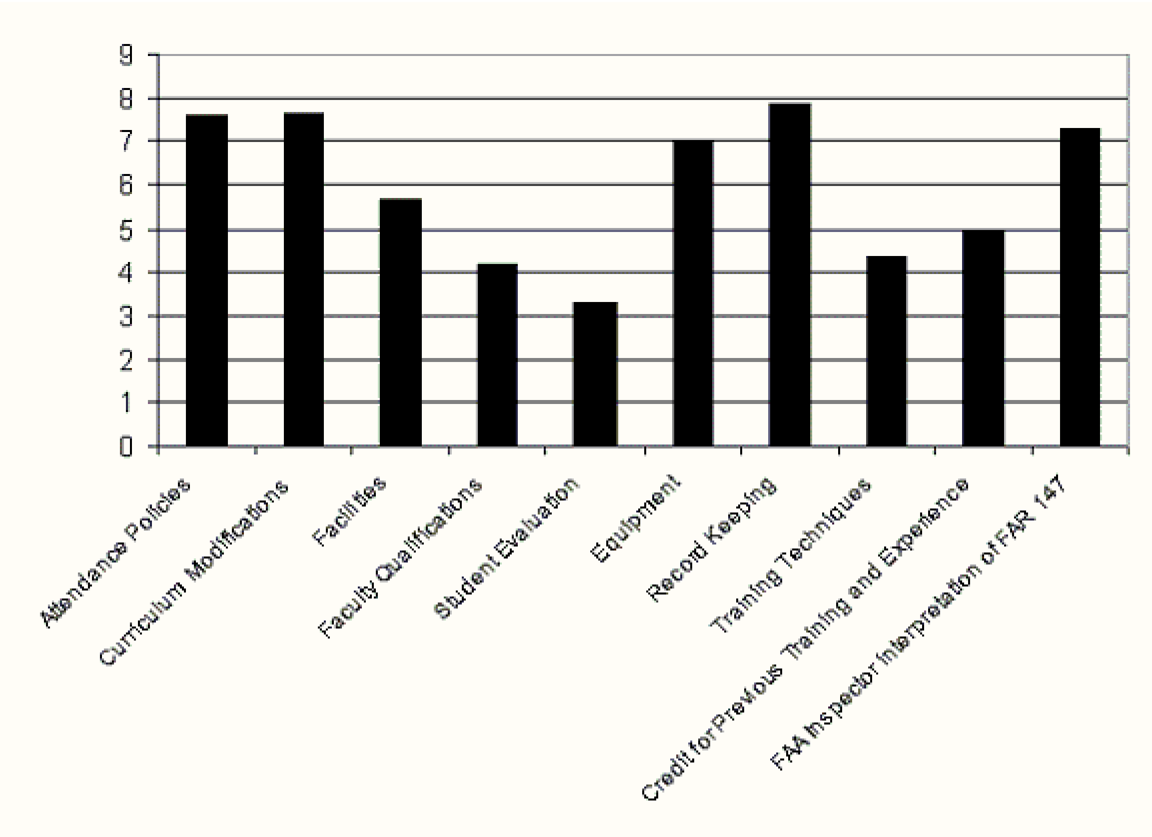

Figure 7.3 Areas Causing the Greatest Problem(s) in the Operation of Approved FAR 147 Programs. #Of Respondents = 75

The above figure shows that when respondents were asked to list their greatest problems in the operation of their FAR 147 program, four of the top five problems, were certification issues: Record Keeping; Attendance Policies; FAA Inspector interpretation of FAR 147; and curriculum modification. The other significant operational problem identified was equipment, which is not a certification issue. Respondents expressed concern with the difficulty and high cost of obtaining equipment. Other problems related to certification but not considered as serious include credit for previous training and experience, student evaluations, faculty qualifications, and training techniques.

The questionnaire results clearly show that from the view of the training provider the present system is not adequately measuring program quality nor encouraging the upgrading of curriculum content. Program administrators and FAA inspectors are clearly more focused on record keeping issues rather than meaningful program improvement. The questionnaire results reveal that making meaningful curriculum changes under the current system of certification and surveillance is unlikely to result in the changes that the industry is requesting.

7.4 BACKGROUND

7.4.1 Enrollment

186 Aviation Maintenance Technician training programs are certified by the Federal Aviation Administration. These programs although similar from the standpoint of meeting minimum curriculum requirements and certification standards vary widely based on their student demographics and program structure.

Aviation maintenance programs are taught at the secondary and post-secondary level in both public and private institutions. The following table illustrates the breakdown of aviation maintenance training programs.

Table 7.2 AMT Program Breakdown by Institution Type

Type of Institution	Number
High School	16
Post-Secondary Vocational (public)	25
Post-Secondary Vocational (proprietary)	38
Community College (2year Institution)	78
College / University (4 year Institution)	29

A study conducted during the 4th quarter of 1998 by the Aviation Technician Education Council (ATEC) obtained responses form 143 member schools. Enrollment in these programs for the 1998 academic year was 11,699. These programs produced 3,338 graduates in 1998. Schools not represented in these numbers tend to be extremely small programs that would have minimal impact on the stated totals.

After several years of declining enrollments, the survey indicates that for the past two years AMT program enrollment has been growing annually at an average of 10 –15%. Close to 70% of the programs are experiencing enrollment growth with expectations that this will continue for the next few years. This continued enrollment growth would be necessary for schools to return to their late

1980's enrollment levels.

7.4.2 Placement Information

In reviewing curriculum content and focus, it is important to periodically review where program graduates are finding employment. As a part of this project, a survey of aviation maintenance training providers was completed during the 2nd quarter of 1998.

The survey results reveal that current employment opportunities cover the entire spectrum of the aviation industry. Two areas of rapid employment growth that were virtually non-existent 25 years ago are the regional airlines and the third- party repair stations.

The survey reveals that the trend of graduates successfully finding airline employment opportunities continues. Approximately two-thirds of graduates finding employment in aviation will work on transport category aircraft or components.

The following chart represents information on 3,872 graduates for the year 1996-97, representing approximately 70% of that year's graduates.

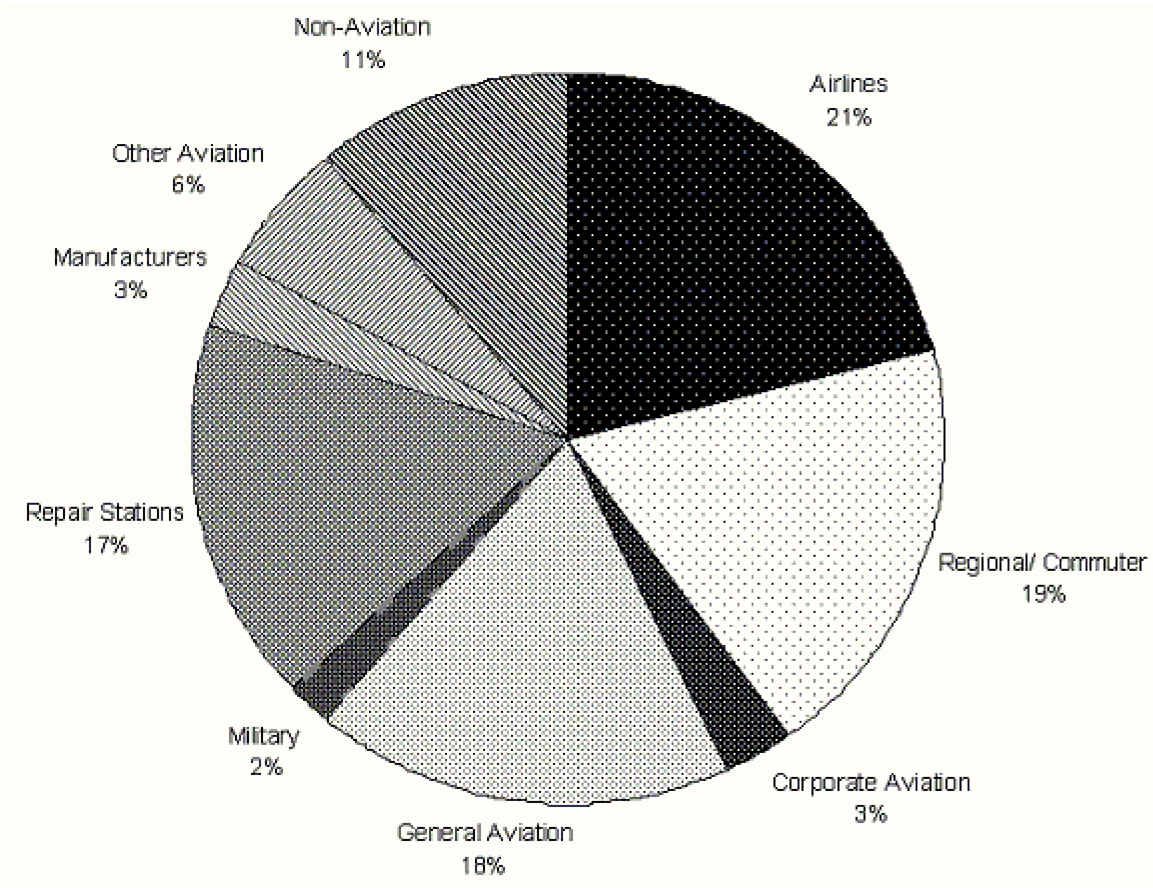

Figure 7.4 Graduates

7.5 CERTIFICATION OF AVIATION MAINTENANCE TECHNICIAN TRAINING PROGRAMS

There are any number of professions in which the establishing and enforcing of standards are of considerable importance. This process often involves two related procedures. First, programs of study must be approved and second, there will exist some procedures for evaluating the competence of those individuals who complete the program of study. As examples, in the field of engineering, educational programs are continually evaluated for purpose of accreditation and graduates must also take a set of exams in order to be certified as a professional engineer. Programs for training teachers, in primary or secondary education, have to be accredited while graduates of those programs are expected to pass some form of examination in order to be certified. Aviation Maintenance Technicians undergo a similar process. Schools for training aviation maintenance personnel must be certified (accredited) by the FAA, while the graduates of these schools must pass a series of tests in order to become licensed.

7.5.1 Present Method

Aviation Maintenance Training programs must meet the requirements of 14 CFR Federal Aviation Regulation Part 147. FAR 147-Aviation Maintenance Technician Schools details the standards of performance and curriculum requirements that aviation maintenance technician training programs must be adhered to. Requirements for individual testing are presented in 14 CFR Federal Aviation Regulation Part 65-Certification: Airman other than Flight Crewmembers.

FAA personnel responsible for the certification and surveillance of aviation maintenance training programs utilize material in FAA Order 8300.10 -Airworthiness Inspectors Handbook and Advisory Circular 147-3 -Certification and Operation of Aviation Maintenance Technician Schools for guidance in performing these tasks.

Individuals seeking the certification as an aviation maintenance technician, after completion of the AMT training program must successfully complete a series of written, oral and practical exams. The written exam(s) also serves as the primary measure of AMT training program quality.

While this system serves to insure that all persons seeking AMT certification have completed certain minimum standards, it also stifles innovation in the education process and only guarantees that the AMT can answer a series of multiple choice questions that are available on the open market complete with the correct answers.

7.5.2 Specific Problems

- Present methods of certification and surveillance do not address the uniqueness of the education process and different student learning styles.
- Places arbitrary and unnecessary burdens on the training provider making it difficult in keeping the curriculum current with technological advances and responsive to industry needs.
- Places excessive requirements on manipulative skills at the expense of cognitive learning.
- Reliance on national testing data to evaluate quality of instruction.
- The surveillance process used to insure compliance with regulatory requirements focuses on specific check list items such as, proper display of Air Agency Certificate and training hours. This process fails to address student learning or curriculum relevance.

7.5.3 14 CFR Federal Aviation Regulation Part 66 - Certification: Aviation Maintenance Personnel

The proposed FAR Part 66 provides for two separate certifications for aviation maintenance technicians based on aircraft certification. The Aviation Maintenance Technician (AMT) holds the authority to maintain and return to service aircraft certified under FAR 23 and 27. The Aviation Maintenance Technician-Transport (AMT-T) holds the authority to maintain and return to service aircraft certified under FAR 25 and 29. In addition, Part 66 provides for the elimination of the Airframe and Powerplant ratings for the AMT certification and the inception of a single rating of Aircraft for both the AMT and AMT-T.

AMT training requirements are detailed in FAR 147. The AMT-T certificate training requirements are integrated into proposed FAR 66. The FAA has funded the development of a training curriculum that integrates the requirements of both FAR 66 and FAR 147.

7.6 AMT/AMT-T INTEGRATED CURRICULUM

The AMT/AMT-T integrated curriculum student performance objectives provide the knowledge, skills and abilities required in both FAR 147 AMT and FAR 66 AMT-T training requirements. The elimination of the Airframe and Powerplant ratings for the AMT certification and the inception of a single rating of Aircraft for both the AMT and AMT-T in proposed FAR Part 66 is reflected in the presentation of the AMT/AMT-T curriculum.

The AMT/AMT-T integrated curriculum provides for 2100 instructional hours. This curriculum is divided into nine (9) instructional units. Each instructional unit contains student performance objectives related to the subject content of the instructional unit. The student performance objectives in certain instructional units are further divided into modules based on subject content. Student performance levels are set for each student performance objective.

Student performance levels provide the minimum standards of acceptable achievement that must be obtained by the student for each student performance objective. Student performance levels are divided into three elements: knowledge, manipulative skills, and application. Each element is further divided into three measures of performance.

Given that this curriculum is performance-outcome based, there is no requirement mandating that a student must complete 2100 hours of instruction. If the student can demonstrate the acceptable level of performance and competency for the student performance objective the program may credit the student for completing the SPO.

7.7 CERTIFICATION STANDARDS FOR AMT-T AND AMT TRAINING PROGRAMS

Certification standards for AMT training programs are detailed in FAR 147.

The standards detail specific requirements certification which includes the areas of ratings; facilities, equipment, and material requirements; space requirements; instructional equipment requirements; materials, special tools and shop equipment requirements; general curriculum requirements; and instructor requirements. Additional requirements for operating rules include; attendance and enrollment, tests, and credit for prior instruction or experience; records; transcripts and graduation certificates; maintenance of instructor requirements; maintenance of facilities, equipment, and material; maintenance of curriculum requirements; quality of instruction; display of certificate; change of location; inspection; and advertising.

Certification standards for AMT-T training programs are detailed in proposed FAR 66.

The standards cover the following items: form of training program outline; content of training program outline; additional subject areas; minimum training program requirements; facilities, equipment, and material; instructors; credit for previous training; revision of training program; student records and reports; statement of graduation and records of training completion; contracts and agreements; change of ownership, name, or location; cancellation of approval.

The performance standards and requirements for AMT certificate training differ significantly from the AMT-T certificate training. These differences make the use of the AMT/AMT-T integrated curriculum impossible use under present certification standards and procedures.

7.8 CERTIFICATION STANDARDS FOR AMT TRAINING PROGRAMS

USING THE AMT–AMT/T INTEGRATED CURRICULUM

The training of aviation maintenance technicians is a complex operation requiring both the imparting of manual skills with a sound knowledge of basic subject theory and a comprehensive understanding of the aircraft or system on which they will have to work. They should have an appreciation of the high value of, and treat accordingly, the aircraft, test equipment and tools, which they will use in their work. Students should be instructed and encouraged to develop safe and neat working routines, a sense of responsibility, technical honesty and integrity. It is the honesty and integrity of the AMT, which in many instances will determine the level of safety of an aircraft. The standards of performance for AMT training insure that graduates will meet the minimum levels of knowledge, skills and abilities to perform normal and routine tasks expected of entry-level maintenance technicians and insure that the graduate is prepared to further develop his/her technical skills and knowledge.

7.8.1 Standards

The standards of performance, detailed in this section, establish the minimum threshold criteria for Aviation Maintenance Technician training programs that utilize the AMT/AMT-T Integrated curriculum. AMT training programs must meet and adhere to these standards to obtain and remain certified by the Federal Aviation Administration.

These standards of performance are not intended to impose upon AMT training programs rigid uniformity of educational objectives or program operations but to provide minimum acceptable levels of performance. It is of paramount importance that AMT training remains current with technology and industry requirements. AMT training programs should operate with the philosophy of "exceeding the minimums". The FAA should support and facilitate efforts in this area.

The following areas of AMT training are addressed to provide the standards of performance for AMT training programs using the AMT/AMT-T curriculum: Curriculum; Instructional Techniques; Faculty; Student Evaluation; Program Operation; Facilities; Equipment; Quality Assurance; Institutional and Financial Support; Industry Advisory Committee. Each area will be dealt with separately in this section.

7.8.2 Curriculum

The curriculum content should provide an integrated educational experience directed toward development of the ability to apply pertinent knowledge and skills to the solution of practical problems. Aviation Maintenance Technician training courses should be applications-oriented with a majority of courses having an accompanying laboratory.

The AMT curriculum should be performance-outcome based with clearly written student performance objectives. The student performance objectives must cover the breadth of knowledge, skills and abilities required to perform the duties expected of the aviation technician in today’s aviation industry.

The AMT curriculum should be presented in instructional units. Each instructional unit should contain the student performance objectives related to the subject content of the instructional unit. The student performance objectives in certain instructional units may be further divided into modules based on subject content. These instructional units and modules may be grouped as necessary to form courses.

Student performance levels must be set for each student performance objective.

Student performance levels provide the minimum standards of acceptable achievement that must be obtained by the student for each student performance objective. Student performance levels should be divided into three elements: knowledge, manipulative skills, and application. Each element further divided into three measures of performance.

7.8.2.1 Course Sequencing

The instructional units in AMT/AMT-T curriculum should be presented in a building block sequence that introduces basic information early in the program so that this knowledge may be utilized in helping the student to learn progressively advanced and diverse subject matter. For this reason it is important that the hierarchical order be followed. Instructional units on the same level may be taught concurrently or in sequence. In some instances, for purposes of student or instructor scheduling it is allowable to begin teaching the next higher instructional level prior to the completion of the previous level.

Student performance objectives should be arranged within the instructional unit, to insure a curriculum flow that allows the student to build on previously learned knowledge and to develop a complete understanding of the subject area.

7.8.2.2 Instructional Techniques

The AMT curriculum should include new subject areas and topical content not previously included in FAR Part 147 aviation maintenance training. The successful teaching of this material will require the utilization of modern educational methods and technology. Where appropriate, educators should be encouraged to utilize accepted educational methods and technology to provide for more effective and efficient training.

One of the guiding concepts behind a properly developed AMT curriculum is that in most subject areas it is possible and desirable to introduce the material related to small, simple aircraft and then progress to large and more complex aircraft. However, it must be remembered that the primary purpose of this curriculum is to prepare technicians for employment in today's industry. For this reason, throughout the curriculum, an emphasis must be placed in the maintenance principles and practices as they relate to transport category aircraft and airline operations.

7.8.2.3 Integration

It is important that general concepts such as safety, team building, human factors, error analysis, computer and technical material usage be emphasized throughout the curriculum and integrated into laboratory situations.

7.9 ACCEPTABLE METHODS OF INSTRUCTION

Since no single method of instruction works for all subject material the AMT curriculum requires the use of various instructional methods. The following are acceptable methods for classroom instruction: lecture; discussion; computer based instruction and demonstration. Practical skills may be taught using individualized projects, group projects, shared projects structured co-op or internships.

7.9.1 Faculty

A well-qualified faculty is the most important component of an aviation maintenance training program. The AMT program must provide an appropriate number of instructors, who are licensed in aircraft maintenance and have experience in an appropriate technical-specialty area.

The faculty of an aviation program must possess the experience, qualifications and capabilities essential for the successful conduct of the program in accordance with the program mission. These qualities include appropriate aviation background, experience, and professional certificates, demonstrated teaching ability, and continued professional development.

An aircraft maintenance training program should have a balanced staff of persons suitably qualified in all the subjects listed in its curriculum. The instructors of technical airframe and engine subjects should be certificated AMT instructors. However, non-certificated instructors may possess the appropriate subject or technical competency to provide instruction in many required subject areas. The school must be able to present convincing evidence that each member of its educational and administrative staff is fully qualified to perform their assigned duties.

7.9.1.1 Instructor to Student Ratio

A sufficient number of faculty members are required to give adequate attention to each student in the program. The appropriate student-faculty ratio will vary greatly and depend on the nature of the courses and activity. For some subjects a large lecture may be suitable while for other laboratory activities the ratio must be kept much smaller.

Although the overall ratio of instructors to students may be about one to twenty, the ratio of instructors to students should be greater for practical training than for classroom work, particularly for practical work performed on airframes, engines or components. A ratio of one instructor for every ten students should be considered appropriate for practical training.

Instructors in most vocational / technical programs are not proficient in more than three or four separate subjects and the average instructor with an aircraft maintenance technicians license might have coped with all subjects in structures, systems and powerplants of the piston engine era, additional instructors may be required to cover the more advanced technical material in today's AMT curriculum.

An aviation maintenance program should insure that at least two instructors are qualified to teach each subject area (course). This insures continuity of instruction in the event of one instructor being absent.

7.9.1.2 Instructor Duties

In addition to the classroom and laboratory teaching duties, it is imperative that instructors be allowed sufficient time for lesson planning, developing and grading student tests and practical projects, preparing training aids and lectures, and keeping abreast of current developments in aviation and technology.

7.9.1.3 Professional Development

The field of aviation maintenance technology is changing rapidly. Thus, the currency of material being taught and the people teaching the material are of paramount concern. Faculty members must maintain current knowledge of their field and understanding of the tasks industry expects technicians to perform. Faculty members normally remain current by active participation in professional societies, reading industry publications and continuing technical education activities. A school should have a well-planned, adequately funded, and effective program for the professional development of its faculty.

7.9.1.4 Evaluation

The organization must have policies and procedures in place to ensure the evaluation of Instructors. The purpose of faculty evaluations is to insure teaching effectiveness, accountability, professional development, and service to students.

The Department Chair (or similar position) will conduct instructor evaluations on at least an annual basis. New instructors should be evaluated more frequently. The instructor evaluation process may include many different inputs ranging from administrative and/or peer evaluations to student evaluations. The Department Chair should observe the instructor in both the classroom and laboratory.

The evaluation of all regular and part-time faculty, along with appropriate follow-up action where necessary, should ensure teaching effectiveness, conformance of presentations to course objectives, technical accuracy, and lead to continued program improvement.

7.9.2 Laboratory Assistants

A program may consider the use of laboratory assistants. The function of the laboratory assistant is to provide additional supervision and instructional support during laboratory instruction. Laboratory assistants should possess the appropriate knowledge and skills for the area being taught. Lab Assistants must always function under the direct supervision of the course instructor. Lab Assistants should not be used for lecturing or other similar activities.

7.10 EVALUATION OF STUDENT PERFORMANCE

Aircraft maintenance is subject to rapid evolution and the frequent introduction of new technology and equipment. As a consequence, both the training and evaluation must keep abreast of developments. A comprehensive evaluation system that monitors and assesses student progress and performance is required. There are several different components that should comprise an evaluation system. Since the duties of an aircraft maintenance technician require both mental and manual abilities, excellent diagnostic techniques and considerable ingenuity, the evaluation process should include practical examinations in addition to the written, computer-based, and oral ones. However, since a comprehensive practical examination is time consuming and generally difficult to administer, a program may dispense with formal summative practical examinations and assess the student's practical work throughout the period of training.

In most circumstances, the student's level of technical accomplishment is determined, to a large extent by written examinations administered throughout and at the end of training. Other criteria though, such as total performance throughout a period of training, should also be taken into consideration.

7.10.1 Purposes of Tests

Examinations can serve several different functions. Tests can help evaluate the effectiveness of classroom presentations by determining how well students understand and retain the information presented. Tests can also reveal the extent of prior or background knowledge students bring to a program. Tests generally fall into one of four categories depending upon the purpose for which they are used:

A. Entry or Placement Tests should be administered before instruction begins and is used to determine if the student has the prerequisite skills or knowledge to undertake a course or unit of instruction.

B. Pretests (or test-out) are administered before the instruction begins, and are used to determine if the student has already mastered the objectives for a course. These may be used if the student has previous civilian or military experience.

C. Formative Tests are administered during instruction. They measure student progress and identify learning difficulties. These instructor-administered examinations and are generally counted as part of the student's grade.

D. Summative Test or Posttests are administered after instruction ends and determine the extent to which the student has achieved the instructional objectives.

Evaluation tools used in AMT training programs are generally criterion-referenced. Criterion evaluation compares each student's performance with an established criterion or standard. Student Performance Objectives (SPOs) that are listed in the curriculum guide will provide the criteria the needs to be met. Each student is compared individually with these criterion-referenced standards.

7.10.2 Types of Classroom Tests

Tests also may be classified according to the type of student response that is required.

A. Objective Tests require students to select a correct response or answer from a number of alternatives or supply a missing word or phrase. Students receive scores based on the exact number of right and wrong answers. Examples of objective tests are true-false, matching, and multiple-choice tests.

B. Subjective Tests require students to organize their thoughts and present their answers in a narrative form. Students receive scores based on an individual grader's assessment of the narrative answers. Examples of subjective tests are short answer and essay tests.

Written examinations are either of the objective type or the essay type and there are several variations of each. Both types of examination have their merits. In general it may be said that it would probably be unwise to make all progress tests and examinations given during a course entirely of one type or the other. Evaluations covering subjects such as weight & balance, electrical or radio theory must obviously include problems to be solved by mathematical means, and this often precludes certain multiple choice questions. Tests on airframes, engines or equipment may require a student to explain the principles and behavior of structures or systems and the examiner may best assess the quality of a student's knowledge by questions of the "sketch and describe" type. The multiple choice type is most useful as a test of the "quantity" and "precision" of a student's knowledge and may be used where accurate memorization of facts is the required objective of the training. The essay type examination is more useful when an assessment of the student's ability to analyze is required.

7.10.3 General Guidelines for Developing Tests

A. Design the test or evaluation based upon the stated objectives. Be certain that each test item matches one of the objectives as closely as possible.

B. Identify the subject matter and the objectives to be tested.

C. Prepare a chart listing the objectives and content to be tested, the number of test items desired for each area and the level of difficulty for each item.

D Using the chart as a guide, select the type of questions, which most appropriately fit the content and objectives.

E. Prepare the test by gathering items together. Keep in mind the test length, overall difficulty, directions to students, ease of administration, and potential problems with scoring.

F. Avoid providing clues to one question's answer in another question.

G. Avoid ambiguous or trick questions.

H. Avoid items dealing with trivia.

Examinations should be reviewed regularly by the Department Chair (or similar position) and instructors for the following:

i. question relevancy, clarity and structure

ii. current/up-to-date technological content

iii. ensure exams are acceptable for the type course in question.

iv. ensure minimum competency is being achieved. review of suggested revision/changes to exams

7.10.4 Grading

The main problem with criterion-referenced evaluation is determining what level of achievement constitutes mastery and how to assign letter grades. The grading system and standards to be used are left up to the individual programs to establish. However, whatever system is utilized it is important that it clearly identifies if the students have satisfactorily met criteria and completed the requirements for the SPOs listed against that course or unit. The minimum score for mastery (for example, 70 percent) should be determined, and the test difficulty designed with that score in mind. A method should be established for students who have failed a course or unit to remediate this work. This remediation may require the student to repeat the entire course or unit, or if the failed material can be clearly identified, only the applicable material need be repeated.

7.10.5 Evaluation of Practical Skills

The evaluation of practical skills is difficult and subjective yet must be accomplished to insure that the student has mastered the necessary skills. Programs must set clear standards for acceptable performance and all faculty members must consistently apply these standards.

These standards will vary from project to project. All students should be instructed as to what is acceptable performance prior to beginning the practical task. Elements to consider in evaluating practical work should include: proper use of tools and equipment; safe work practices; proper use of technical data; teamwork and related human factors skills; quality of final work (i.e. proper operation or airworthiness); and material usage (i.e. waste).

7.11 FACILITIES

The school must provide suitable classrooms and laboratories adequate to accommodate the largest number of students scheduled for attendance at any one time. All facilities must conform to applicable Federal, State, and local safety and environmental codes. All facilities must be continually maintained to at least the same standards under which the most recent approval is granted.

7.11.1 Classrooms

Classrooms shall be properly heated, lighted, and ventilated to perform they designated purpose. Classrooms should be located so that noise form aircraft and lab activities do not interfere with lectures or other classroom functions. The size of the classroom will depend on the number of students seated at any one time, audiovisual equipment to be used, and if demonstrations will be performed in the classroom. Each student must be provided with adequate space for note taking and other tasks. Programs should also consider the duration of time in which a student may be required to be in the classroom when selecting seating.

7.11.2 Laboratory Facilities

Lab space must be adequate for its use. All lab space must be properly lighted with the necessary climate control for the location and use.

Engine shops should include storage for engine parts and related components. Parts cleaning equipment and other needed power equipment.

7.12 LEARNING RESOURCES

The program must have suitable equipment and training devices to perform the instruction as detailed in the student performance objectives. This equipment shall include but not be limited to aircraft, training aids, test equipment, special tools, and technical software packages. This equipment must be suitable for transport category aircraft where specified. Is incumbent upon the school to present evidence that the equipment is available and in sufficient quantity to permit students to successfully complete all specified practical projects.

Technical data reference material that includes, but is not limited to, Federal Aviation Regulations, FAA Advisory Circulars, manufacturer manuals and technical publications must be available and maintained at an appropriate currency to provide for students to complete required projects.

Instructional and learning media resources should be available and maintained to contemporary standards.

AMT training programs are increasingly dependent upon the use of computers for certain types of student instruction. The computer facilities available to the student and staff, therefore, must reflect these requirements to encourage the use of computers by providing accessibility and availability as a part of the curriculum.

7.13 ADVISORY COMMITTEES

It is recognized that advisory committees can contribute significantly to the growth and development of an aviation maintenance technician training program as a means of assuring technical currency of the program and maintaining close working relationship with the supporting and employing industries.

Each certified program must have a functional advisory committee composed of aviation industry representatives, which must meet at least annually.

The advisory committee should be broad-based and composed primarily of individuals actively engaged in the aviation maintenance technology field. The members should have an intimate knowledge of the current work of AMT technicians and the work they are likely to do in the near future.

The committee should meet a minimum of once a year with the administration, faculty and students to discuss program needs, progress, and problems, and to recommend solutions. In addition to the annual meeting regular communication should occur with the committee throughout the year.

To be effective, advisory committees must be properly supported, logistically and administratively. They should be given meaningful assignments that are properly within their areas of expertise, and their advice must be given serious consideration. The advisory committee should periodically review curriculum and course content to ensure that the current and future needs of the aviation maintenance industry are being met.

7.14 CONTINUOUS QUALITY IMPROVEMENT

Continuous Quality Improvement is an ongoing process aimed at understanding and improving program quality and student learning. It involves setting appropriate criteria and high standards for learning quality; systematically gathering, analyzing, and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document explain, and improve performance. When it is integrated into an AMT training program it can effectively improve the quality of the training.

Assessment attempts to answer two questions. Is the material being taught current and relevant? Is the material being taught effectively? An effective assessment program should contain the following principles:

1. Assesses what we teach - and what we expect students to learn.
2. Provides information regarding curriculum strengths & weaknesses.
3. Focuses on process as well as on outcomes.
4. Actively involves teachers and students.
5. Provides information for improving learning.
6. Uses multiple and varied measures.
7. Is carried out at various key points.
8. Provides feedback to those most affected.

Assessment is an integral part of a continuous improvement program. Each AMT/AMT-T certified program should have in place a continuous improvement program. The idea of such a program is to not only improve the classroom instruction but also to continuously integrate new technology into the curriculum. Information gathered from assessment activities will assist in identifying areas that can be targeted for change.

A sample continuous improvement process is shown below.

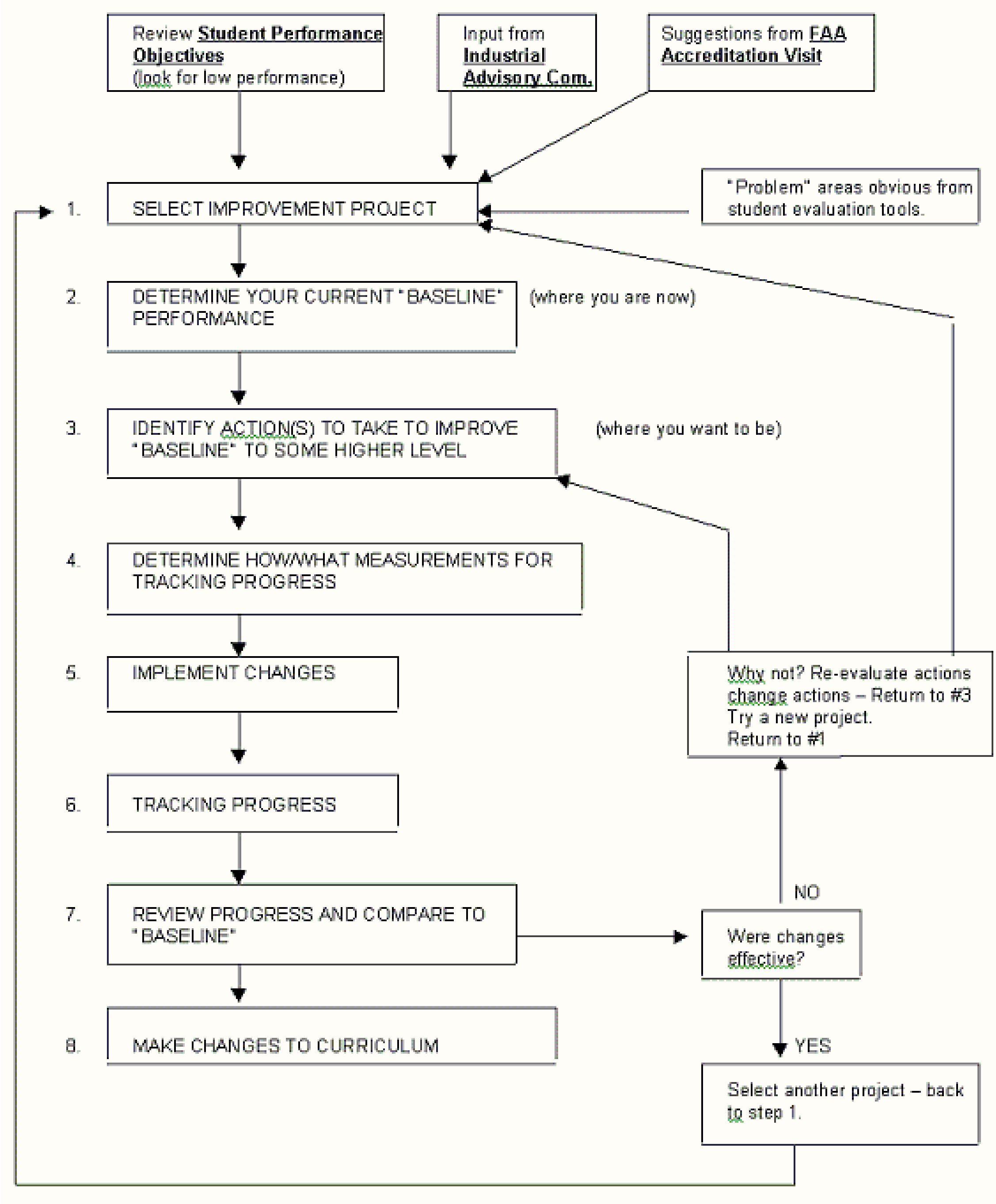

Figure 7.5 Continuous Improvement Process

7.15 APPENDIX A
Student Performance Objectives

General Knowledge

SPO Item #	Student Performance Levels			Student Performance Objecti
	Knowledge	Application	Manipulative Skills	
				Demonstrate the ability to perform mathematica

GK 1	**C**	**C**	**A**	**extract roots and raise numbers to a given power**
GK 2	**C**	**C**	**A**	**Demonstrate the ability to perform mathematica determine areas and volumes of various geometr**
GK 3	**C**	**C**	**A**	**Demonstrate the ability to perform mathematica solve ratio, proportion, and percentage problems**
GK 4	**C**	**C**	**A**	**Demonstrate the ability to perform algebraic op addition, subtraction, multiplication, and divisio negative numbers**
GK 5	**B**	**B**	**A**	**Demonstrate the ability to identify and explain t simple machines**
GK 6	B	B	A	Demonstrate the ability to identify and explain the p
GK 7	B	B	A	Demonstrate the ability to identify and explain the p dynamics
GK 8	C	C	A	Demonstrate the ability to identify and explain the f secondary structural and flight control components certified under FAR Part 23, 25, 27 and 29
GK 9	C	B	A	Demonstrate the ability to identify and explain the p aerodynamics as they relate to aircraft certified und 23,25,27,and 29
GK 10	**C**	**B**	**A**	**Demonstrate the ability to state and explain the p theory of flight for fixed and rotary wing aircraf**
GK 11	**B**	**C**	**A**	**Demonstrate the ability to identify FAA type cer**
GK 12	**C**	**C**	**B**	**Demonstrate the ability to perform basic functio computer using typical desktop application prog**
GK 13	**C**	**C**	**B**	**Demonstrate the ability to input data to a compu words per minute**
GK 14	**B**	**B**	**A**	**Demonstrate the ability to state and explain the l procedures used in troubleshooting**
GK 15	B	B	A	Demonstrate the ability to state and explain the con Maintenance Resource Management – Human Facto
GK 16	B	B	A	Demonstrate the ability to state and explain the con Building
GK 17	B	B	A	Demonstrate the ability to state and explain the con Situational Awareness

GK 18	B	B	A	Demonstrate the ability to state and explain the con Analysis
GK 19	C	C	A	Demonstrate the ability to read and comprehend air and related materials
GK 20	C	C	A	Demonstrate the ability to write in the English lang defect and repair statements
GK 21	C	C	A	Demonstrate the ability to speak the English langua explaining aircraft technical material

Basic Maintenance Knowledge & Skills

SPO Item #	Student Performance Levels Knowledge	Application	Manipulative Skills	Student Performance Objective
MKS 1	**B**	**A**	**A**	**Demonstrate the ability to use aircraft drawings, system schematics to perform aircraft maintenan**
MKS 2	**B**	**B**	**B**	**Demonstrate the ability to draw sketches of aircr alterations**
MKS 3	**C**	**C**	**A**	**Demonstrate the ability to locate and identify inf blueprints and technical drawings**
MKS 4	**C**	**C**	**A**	**Demonstrate the ability to locate, calculate and c information found on charts and graphs**
MKS 5	**C**	**C**	**B**	**Demonstrate the ability to weigh aircraft certifie 23**
MKS 6	C	C	A	Demonstrate the ability to identify and perform the to complete weight-and-balance checks and record operated under FAR Part 91 and 121
MKS 7	C	C	C	Demonstrate the ability to fabricate, proof test and i flexible fluid lines and fittings
MKS 8	B	A	A	Demonstrate the ability to identify cleaning material aircraft exterior structures
MKS 9	B	A	A	Demonstrate the ability to identify aircraft corrosion corrective and preventive treatment
				Demonstrate the ability to identify appropriate nond

MKS 10	B	A	A	methods for various aircraft and engine applications
MKS 11	**B**	**B**	**B**	**Demonstrate the ability to perform basic dye penetrant, eddy curr magnetic particle Inspections**
MKS 12	**B**	**A**	**A**	**Demonstrate the ability to identify basic heat processes for various aircraft and engine applications**
MKS 13	**C**	**A**	**A**	**Demonstrate the ability to identify and determine the s required for aircraft material and hardware on variou**
MKS 14	**C**	**C**	**A**	**Demonstrate the ability to inspect welds to determine a**
MKS 15	**C**	**C**	**C**	**Demonstrate the ability to operate precision measuring**
MKS 16	C	A	A	Demonstrate the ability to identify and select the proper fa and Determine acceptable fastener substitution for various and engine applications
MKS 17	A	A	A	Demonstrate the ability to identify common hand tools and common specialty tools
MKS 18	A	A	A	Demonstrate the ability to layout and apply registration let numbers
MKS 19	A	A	A	Demonstrate the ability to identify and select proper aircra materials
MKS 20	B	B	A	Demonstrate the ability to inspect aircraft exterior finishes Identify defects in the finish and their cause
MKS 21	C	C	C	Demonstrate the ability to correctly safety aircraft bolts, nu turnbuckles and connectors
MKS 22	C	C	C	Demonstrate the ability to remove and install aircraft studs coil Inserts
MKS 23	C	C	C	Demonstrate the ability to install and repair threads in/on a and steel

Aircraft Documentation and Administrative Skills

SPO	Student Performance Levels	Student Performance Objecti

Item #	Knowledge	Application	Manipulative Skills	
ADAS 1	**C**	**C**	**A**	**Demonstrate the ability to write descriptions of w including aircraft discrepancies and corrective ac aircraft maintenance records for aircraft operati and 121**
ADAS 2	**C**	**C**	**A**	**Demonstrate the ability to properly complete req forms, records, and inspection reports for aircraf FAR Part 91 and 121**
ADAS 3	**C**	**C**	**A**	**Demonstrate the ability to read, comprehend, loc information contained in Minimum Equipment L Configuration Deviation List (CDL), and Dispatc guide (DDPG)**
ADAS 4	**C**	**C**	**A**	**Demonstrate the ability to read, comprehend, loc information contained in FAA Type Certificate D Airworthiness Directives, Advisory Circulars, an Aviation Regulations**
ADAS 5	**C**	**C**	**A**	**Demonstrate the ability to read, comprehend, loc information contained in manufacturer aircraft and engines**
ADAS 6	C	C	A	Demonstrate the ability to read, comprehend, locate contained in manufacturer's Engine Maintenance M
ADAS 7	**C**	**C**	**A**	**Demonstrate the ability to read, comprehend, loc information contained in manufacturer Manual (FRM & FIM)**
ADAS 8	**C**	**C**	**A**	**Demonstrate the ability to read, comprehend, loc information contained in manufacturer for aircraft certified under Part 23 and 25**
ADAS 9	**C**	**C**	**A**	**Demonstrate the ability to read, comprehend, loc information contained in manufacturer Manuals for aircraft certified under Part 23 and**
ADAS 10	**C**	**C**	**A**	**Demonstrate the ability to read, comprehend, loc information contained in manufacturer Manual**
ADAS 11	**C**	**C**	**A**	**Demonstrate the ability to read, comprehend, loc information contained in manufacturer Manuals**
ADAS 12	C	C	A	Demonstrate the ability to read, comprehend, and ap contained in Air Carrier (Pt. 121) Engineering Orde
ADAS 13	C	C	A	Demonstrate the ability to state and explain the Avia Technician and Aviation Maintenance Technician within the limitations prescribed by Part 66
				Demonstrate the ability to identify parts acceptable f aircraft utilizing manufactures, repair station, and ai

ADAS 14	C	B	A	(part) certification paperwork
ADAS 15	**C**	**B**	**A**	**Demonstrate the ability to state and explain the m maintenance release requirements for aircraft op Part 121 and ETOPS**
ADAS 16	**C**	**B**	**A**	**Demonstrate the ability to state and explain tool a calibration requirements**
ADAS 17	**C**	**B**	**A**	**Demonstrate the ability to locate and explain airc Category 3 inspection and release for flight requi**

Ground Operations and Safety

SPO Item #	Student Performance Levels Knowledge	Application	Manipulative Skills	Student Performance Objectiv
GOS 1	**C**	**C**	**B**	**Demonstrate the ability to start, ground operate, aircraft**
GOS 2	**B**	**A**	**A**	**Demonstrate the ability to explain the procedures fueling and defueling aircraft certified under FA**
GOS 3	**C**	**C**	**A**	**Demonstrate the ability to select the appropriate item and identify the various information and wa the MSDS sheet**
GOS 4	**C**	**C**	**A**	**Demonstrate the ability to explain the EPA, OSH procedures for handling hazardous materials on**
GOS 5	**C**	**C**	**A**	**Demonstrate the ability to identify typical hazard ramp and hangar areas**
GOS 6	C	C	A	Demonstrate the ability to explain standard safety pr procedures for working on and around aircraft locate
GOS 7	C	C	A	Demonstrate the ability to locate and explain OSHA practices and procedures for confined space entry
GOS 8	B	B	A	Demonstrate the ability to locate and explain OSHA aircraft maintenance activities
GOS 9	C	C	A	Demonstrate the ability to explain standard safety pr procedures for working around jet blast hazard areas
GOS 10	**B**	**B**	**B**	**Demonstrate the ability to perform aircraft interi powerplant cleaning**

GOS 11	**B**	**A**	**A**	**Demonstrate the ability to explain the general pr purposes of aircraft fuels, lubricants and greases**
GOS 12	**C**	**C**	**B**	**Demonstrate the ability to identify and select airc**
GOS 13	**C**	**C**	**B**	**Demonstrate the ability to identify and select pow**
GOS 14	**C**	**C**	**B**	**Demonstrate the ability to identify and select hyd**
GOS 15	C	C	B	Demonstrate the ability to identify and select aircraf greases
GOS 16	C	C	B	Demonstrate the ability to identify and select propel
GOS 17	B	A	A	Demonstrate the ability to explain the procedures an deicing aircraft operating under FAR Part 121
GOS 18	C	C	C	Demonstrate the ability to use proper hand signals fo movement of aircraft
GOS 19	C	C	C	Demonstrate the ability to use proper voice procedu transmissions

Aircraft Powerplants

Turbine Engines

SPO Item #	**Student Performance Level** Knowledge	Applications	Manipulative Skills	**Student Performance Objectiv**
PPT 1	**C**	**A**	**A**	**Demonstrate the ability to explain the operation c turbine engines and related systems: turbojet, tur and turboshaft**
PPT 2	**C**	**A**	**A**	**Demonstrate the ability to explain the airflow thr turbine engines including bleed and surge recove**
PPT 3	**C**	**A**	**A**	**Demonstrate the ability to explain variable stator vector analysis of airflow in aircraft gas turbine e**
PPT 4	**C**	**A**	**A**	**Demonstrate the ability to identify typical aircraf**
PPT 5	**C**	**A**	**A**	**Demonstrate the ability to locate and identify typ turbine engine components by proper nomenclatu**
				Demonstrate the ability to identify the materials use

PPT 6	C	A	A	of aircraft gas turbine engines
PPT 7	B	B	B	Demonstrate the ability to overhaul an aircraft gas tu
PPT 8	C	C	C	Demonstrate the ability to perform routine maintena gas turbine engines
PPT 9	C	C	C	Demonstrate the ability to inspect aircraft gas turbin
PPT 10	C	B	B	Demonstrate the ability to troubleshoot operational r aircraft gas turbine engine
PPT 11	**C**	**C**	**C**	**Demonstrate the ability to remove and install airc engines**
PPT 12	**C**	**C**	**C**	**Demonstrate the ability to adjust and rig aircraft controls**
PPT 13	C	C	B	Demonstrate the ability to identify and assess damag turbine engine fan blades and vanes, compressor bla blades and vanes, and combustion chambers using v methods
PPT 14	C	B	A	Demonstrate the ability to explain the concepts and p aircraft gas turbine engine trend monitoring
PPT 15	C	B	A	Demonstrate the ability explain the following aircraf maintenance concepts: Hard Time, Soft Time, On C
PPT 16	C	A	A	Demonstrate the ability to state and explain the spec required on aircraft gas turbine engines
PPT 17	C	C	B	Demonstrate the ability to perform routine borescope aircraft gas turbine engines
PPT 18	C	C	C	Demonstrate the ability to start, ground run, perform and shutdown an aircraft gas turbine engine
PPT 19	C	C	C	Demonstrate the ability to identify and select lubrica in aircraft gas turbine engines and on engine installa
PPT 20	C	B	A	Demonstrate the ability to identify and explain the p components in aircraft gas turbine engine lubricatior and unregulated
PPT 21	C	C	C	Demonstrate the ability to service an aircraft gas turb systems
PPT 22	**C**	**B**	**C**	**Demonstrate the ability to perform routine maint aircraft gas turbine engine lubrication systems ar components**

PPT 23	**C**	**B**	**B**	**Demonstrate the ability to troubleshoot operation aircraft gas turbine engine lubrication systems ar components**
PPT 24	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft gas tur lubrication systems**
PPT 25	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th the components in aircraft gas turbine engine ign**
PPT 26	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft gas tur systems**
PPT 27	C	B	B	Demonstrate the ability to troubleshoot operational r aircraft gas turbine engine ignition system and syster
PPT 28	C	B	C	Demonstrate the ability to perform routine maintena gas turbine engine ignition systems and system comp
PPT 29	C	B	A	Demonstrate the ability to identify and explain the p components in aircraft gas turbine engine starting sy
PPT 30	C	C	C	Demonstrate the ability to inspect aircraft gas turbine systems
PPT 31	C	B	B	Demonstrate the ability to troubleshoot operational r aircraft gas turbine engine starting systems and syste
PPT 32	C	B	C	Demonstrate the ability to perform routine maintena gas turbine engine starting systems and system comp
PPT 33	C	B	A	Demonstrate the ability to identify and explain the p components in aircraft gas turbine engine fuel syster
PPT 34	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft gas tur systems and control systems**
PPT 35	**C**	**B**	**C**	**Demonstrate the ability to perform routine maint aircraft gas turbine engine fuel systems, fuel cont components**
PPT 36	**B**	**B**	**C**	**Demonstrate the ability to troubleshoot operation aircraft gas turbine engine fuel systems, fuel cont components**
PPT 37	**B**	**A**	**A**	**Demonstrate the ability to state and explain the o aircraft gas turbine engine electronic engine cont management systems (FADEC) & (EEC)**
PPT 38	B	A	A	Demonstrate the ability to locate and identify typical engine electronic control and thrust management co nomenclature

PPT 39	C	C	C	Demonstrate the ability to inspect aircraft gas turbin systems
PPT 40	C	B	C	Demonstrate the ability to perform routine maintena gas turbine engine ice control system and system co
PPT 41	C	B	C	Demonstrate the ability to troubleshoot operational aircraft gas turbine engine ice control systems and s
PPT 42	C	C	C	Demonstrate the ability to inspect aircraft gas turbin systems and system components
PPT 43	C	B	C	Demonstrate the ability to perform routine maintena gas turbine engine exhaust systems and system com
PPT 44	**C**	**B**	**C**	**Demonstrate the ability to troubleshoot operatio aircraft gas turbine engine exhaust systems and s**
PPT 45	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft gas tu reverser systems and system components**
PPT 46	**C**	**B**	**C**	**Demonstrate the ability to perform routine main aircraft gas turbine engine thrust reverser syste components**
PPT 47	**C**	**B**	**B**	**Demonstrate the ability to troubleshoot operatio aircraft gas turbine engine thrust reverser syste components**
PPT 48	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th the components in aircraft gas turbine engine ele**
PPT 49	C	C	C	Demonstrate the ability to inspect aircraft gas turbin systems and system components
PPT 50	C	B	C	Demonstrate the ability to perform routine maintena gas turbine engine electrical systems and system co
PPT 51	C	B	C	Demonstrate the ability to troubleshoot operational aircraft gas turbine engine electrical systems and sy
PPT 52	C	A	A	Demonstrate the ability to service aircraft gas turbin and accessory drive units (CSD & IGD)
PPT 53	C	A	A	Demonstrate the ability to explain the operation of t Auxiliary Power Units and APU system interface
PPT 54	C	A	A	Demonstrate the ability to identify typical aircraft A
PPT 55	C	A	A	Demonstrate the ability to locate and identify typica Power Unit components by proper nomenclature

PPT 56	B	A	A	Demonstrate the ability to perform routine maint aircraft Auxiliary Power Units
PPT 57	C	A	A	Demonstrate the ability to troubleshoot operation aircraft Auxiliary Power Units

Reciprocating Engines

S P O Item #	Student Performance Level Knowledge	Application	Manipulative Skills	Student Performance Objectiv
PPR 1	C	A	A	Demonstrate the ability to explain the operation c reciprocating engines and related systems
PPR 2	C	A	A	Demonstrate the ability to identify typical aircraf engines
PPR 3	C	A	A	Demonstrate the ability to locate and identify typ reciprocating engine components by proper nome
PPR 4	B	B	B	Demonstrate the ability to overhaul an aircraft re
PPR 5	C	C	C	Demonstrate the ability to perform routine maint repairs on reciprocating engines
PPR 6	C	C	C	Demonstrate the ability to inspect reciprocating e
PPR 7	C	C	C	Demonstrate the ability to remove and install airc engines
PPR 8	C	C	C	Demonstrate the ability to adjust and rig aircraft controls
PPR 9	C	B	C	Demonstrate the ability to troubleshoot operation an aircraft reciprocating engine
PPR 10	C	C	C	Demonstrate the ability to start, perform typical g checks, and shutdown an aircraft reciprocating e
PPR 11	C	C	A	Demonstrate the ability to identify and select lubr aircraft reciprocating engines and on engine insta
PPR 12	C	C	C	Demonstrate the ability to service aircraft recipro lubrication systems

PRP 13	C	B	A	Demonstrate the ability to identify and explain th of the components in aircraft reciprocating engin
PPR 14	C	C	C	Demonstrate the ability to inspect aircraft recipr lubrication systems and system components.
PPR 15	C	B	C	Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine lubricati system components
PPR 16	C	B	C	Demonstrate the ability to troubleshoot operation aircraft reciprocating engine lubrication systems components
PPR 17	C	B	A	Demonstrate the ability to identify and explain th of the components in aircraft reciprocating engin
PPR 18	C	C	C	Demonstrate the ability to inspect aircraft recipr ignition systems and system components.
PPR 19	C	B	B	Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine ignition s components
PPR 20	C	B	C	Demonstrate the ability to troubleshoot operation aircraft reciprocating engine ignition systems anc
PPR 21	C	B	C	Demonstrate the ability to overhaul an aircraft m
PPR 22	C	B	A	Demonstrate the ability to identify and explain th of the components in aircraft reciprocating engin
PPR 22	C	C	C	Demonstrate the ability to inspect aircraft recipr systems, fuel metering systems and system compo
PPR 23	C	B	B	Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine fuel syste systems and system components
PPR 24	C	B	B	Demonstrate the ability to troubleshoot operation aircraft reciprocating engine fuel systems, fuel m system components
PRP 25	C	B	A	Demonstrate the ability to identify and explain th of the components in aircraft reciprocating engin induction systems
PPR 26	C	C	C	Demonstrate the ability to inspect aircraft recipr and air induction systems and system component
PPR 27	C	B	C	Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine fuel and and system components

PPR 28	C	B	C	Demonstrate the ability to troubleshoot operation aircraft reciprocating engine fuel and air inductio system components
PPR 29	C	C	C	Demonstrate the ability to inspect aircraft recipro temperature control systems and system compone
PPR 30	C	B	C	Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine temperat and system components
PPR 31	C	B	C	Demonstrate the ability to troubleshoot operation aircraft reciprocating engine temperature contro components
PPR 32	C	C	C	Demonstrate the ability to inspect aircraft recipro exhaust systems and system components.
PPR 33	C	B	C	Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine exhaust s components
PPR 34	C	B	B	Demonstrate the ability to troubleshoot operation aircraft reciprocating engine exhaust systems anc
PPR 35	C	B	A	Demonstrate the ability to identify and explain th of the components in aircraft reciprocating engin systems
PPR 36	C	B	B	Demonstrate the ability to inspect aircraft recipro supercharging systems and system components.
PPR 37	B	B	B	Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine turbo and system components
PRP 38	C	B	C	Demonstrate the ability to troubleshoot operation aircraft reciprocating engine turbo-supercharging components
PPR 39	C	B	A	Demonstrate the ability to identify and explain th of the components in aircraft reciprocating engin
PPR 40	C	C	C	Demonstrate the ability to inspect aircraft recipro starting systems and system components.
PPR 41	B	B	B	Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine starting s components
PPR 42	C	B	C	Demonstrate the ability to troubleshoot operation aircraft reciprocating engine starting systems anc
PPR 43	C	B	A	Demonstrate the ability to identify and explain th of the components in aircraft reciprocating engin

PPR 44	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft recipro electrical systems and system components.**
PPR 45	**C**	**B**	**C**	**Demonstrate the ability to perform routine maint repairs on aircraft reciprocating engine electrical components**
PPR 46	**C**	**B**	**C**	**Demonstrate the ability to troubleshoot operation aircraft reciprocating engine electrical systems an components**

Propellers

S P O Item #	**Student Performance Level** Knowledge	Application	Manipulative Skills	**Student Performance Objectiv**
PPP 1	**C**	**A**	**A**	**Demonstrate the ability to identify and explain th aerodynamics as they relate to the operation of ai**
PPP 2	**C**	**A**	**A**	**Demonstrate the ability to explain the operation o propeller on a reciprocating engine**
PPP 3	**C**	**A**	**A**	**Demonstrate the ability to explain the operation o propeller on a turboprop engine**
PPP 4	**C**	**A**	**A**	**Demonstrate the ability to identify typical aircraf**
PPP 5	**C**	**A**	**A**	**Demonstrate the ability to locate and identify airc by proper nomenclature**
PPP 6	C	C	C	Demonstrate the ability to remove and install aircraf
PPP 7	C	C	C	Demonstrate the ability to adjust and rig aircraft pro
PPP 8	C	C	C	Demonstrate the ability to inspect aircraft propeller a system installations
PPP 9	C	B	B	Demonstrate the ability to perform routine maintena propellers and propeller control systems
PPP 10	C	B	B	Demonstrate the ability to troubleshoot operational r aircraft propeller systems
PPP 11	**C**	**C**	**C**	**Demonstrate the ability to lubricate an aircraft p**
				Demonstrate the ability to explain the principles o

PPP 12	**B**	**B**	**B**	**balancing and blade tracking**
PPP 13	**C**	**A**	**A**	**Demonstrate the ability to explain the principles ice control systems**
PPP 14	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft propel systems**
PPP 15	**C**	**B**	**B**	**Demonstrate the ability to perform routine maint aircraft propellers ice control systems**
PPP 16	C	B	B	Demonstrate the ability to perform routine repairs o propeller blades
PPP 17	C	B	B	Demonstrate the ability to inspect composite propell and lighting strikes
PPP 18	C	B	B	Demonstrate the ability to inspect and perform routi composite propeller blades
PPP 19	C	B	A	Demonstrate the ability to identify, locate and replac replaceable units

Aircraft Electronics and Integrated Systems

Electrical Theory

SPO Item #	**Student Performance Levels** Knowledge	Application	Manipulative Skills	**Student Performance Objectiv**
AEIS – ET 1	**C**	**C**	**A**	**Demonstrate the ability to define and explain con mega, milli, micro, pico**
AEIS – ET 2	**B**	**A**	**A**	**Demonstrate the ability to define atom, electron, ion**
AEIS – ET 3	**B**	**A**	**A**	**Demonstrate the ability to define insulator, condu and ampere**
AEIS – ET 4	**B**	**B**	**A**	**Demonstrate the ability to identify schematic sym electronic components**
AEIS – ET 5	**B**	**A**	**A**	**Demonstrate the ability to define electromotive fo difference, voltage and volt**

AEIS – ET 6	B	A	A	Demonstrate the ability to explain the effects of con series, parallel, and series-parallel
AEIS – ET 7	B	A	A	Demonstrate the ability to explain the difference bet and voltage drop
AEIS – ET 8	B	A	A	Demonstrate the ability to define resistance, ohm an
AEIS – ET 9	B	A	A	Demonstrate the ability to explain resistor constructi
AEIS – ET 10	B	A	A	Demonstrate the ability to explain the operation of a rheostat
AEIS – ET 11	**C**	**C**	**A**	**Demonstrate the ability to write and apply Ohm parallel and series-parallel dc circuits**
AEIS – ET 12	**B**	**A**	**A**	**Demonstrate the ability to define and explain pov**
AEIS – ET 13	**B**	**B**	**A**	**Demonstrate the ability to state and apply basic p**
AEIS – ET 14	**B**	**A**	**A**	**Demonstrate the ability to state and explain the b magnetism**
AEIS – ET 15	**B**	**A**	**A**	**Demonstrate the ability to define and explain ma and permeability**
AEIS – ET 16	B	A	A	Demonstrate the ability to identify the instruments u current, voltage and resistance
AEIS – ET 17	C	B	C	Demonstrate the ability to properly use a ammeter, v ohmmeter
AEIS – ET 18	C	B	A	Demonstrate the ability to define and explain AC an
AEIS – ET 19	B	A	A	Demonstrate the ability to identify a sine wave
AEIS – ET 20	B	B	A	Demonstrate the ability to determine the peak value, and effective value of a sine wave
AEIS – ET 21	B	B	A	Demonstrate the ability to compute peak value wher
AEIS – ET 22	B	A	A	Demonstrate the ability to define and explain hertz, megahertz
AEIS – ET 23	B	B	A	Demonstrate the ability to compute wavelength whe
AEIS – ET 24	C	B	B	Demonstrate the ability to identify and explain the u oscilloscope

AEIS – ET 25	**B**	**B**	**B**	**Demonstrate the ability to measure amplitude, pe using an oscilloscope**
AEIS – ET 26	**B**	**A**	**A**	**Demonstrate the ability to define and explain ind mutual inductance**
AEIS – ET 27	**B**	**A**	**A**	**Demonstrate the ability to explain loss in a transf**
AEIS – ET 28	**B**	**A**	**A**	**Demonstrate the ability to define and explain rea impedance**
AEIS – ET 29	**B**	**B**	**A**	**Demonstrate the ability to calculate inductive rea inductance and impedance**
AEIS – ET 30	B	B	A	Demonstrate the ability to state and apply the formu reactance
AEIS – ET 31	B	A	A	Demonstrate the ability to define and explain capaci capacitive reactance
AEIS – ET 32	B	A	A	Demonstrate the ability to explain impedance match
AEIS – ET 33	B	A	A	Demonstrate the ability to identify and explain the fa capacitance
AEIS – ET 34	B	B	A	Demonstrate the ability to calculate total capacitance connected in series and parallel
AEIS – ET 35	B	B	A	Demonstrate the ability to calculate capacitive reacta
AEIS – ET 36	B	B	A	Demonstrate the ability to calculate total inductance connected in series and parallel
AEIS – ET 37	B	B	A	Demonstrate the ability to calculate the impedance o circuits and parallel RLC circuits
AEIS – ET 38	B	A	A	Demonstrate the ability to define and explain resona
AEIS – ET 39	**B**	**A**	**A**	**Demonstrate the ability to explain the characteristics of resonant circuits**
AEIS – ET 40	**B**	**A**	**A**	**Demonstrate the ability to explain the difference betwe type semiconductor materials**
AEIS – ET 41	**B**	**A**	**A**	**Demonstrate the ability to identify forward and reverse**
AEIS – ET 42	**B**	**A**	**A**	**Demonstrate the ability to name and explain solid**
				Demonstrate the ability to identify and explain the characteristics diodes

AEIS – ET 43	**B**	**A**	**A**	
AEIS – ET 44	B	B	A	Demonstrate the ability to identify the schematic symbols o diode, a zener diode and a varactor diode
AEIS – ET 45	B	B	A	Demonstrate the ability to identify the schematic symbols f transistors
AEIS – ET 46	B	B	A	Demonstrate the ability to identify the correct bias for the e collector-base junctions of a transistor
AEIS – ET 47	B	A	A	Demonstrate the ability to identify and explain the characte common-emitter, common-base and common-collector am configurations
AEIS – ET 48	B	A	A	Demonstrate the ability to name and explain the three basic configurations
AEIS – ET 49	B	A	A	Demonstrate the ability to define and explain light, infrared rays and photon
AEIS – ET 50	B	A	A	Demonstrate the ability to identify and explain the light sp range
AEIS – ET 51	B	A	A	Demonstrate the ability to name and explain the characteri sensitive devices
AEIS – ET 52	**B**	**B**	**A**	**Demonstrate the ability to identify the schematic sensitive devices**
AEIS – ET 53	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p emitting diode (LED)**
AEIS – ET 54	**B**	**A**	**A**	**Demonstrate the ability to explain the operating c modes of a liquid crystal display**
AEIS – ET 55	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th two basic types of integrated circuits**
AEIS – ET 56	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th digital integrated circuits**
AEIS – ET 57	B	A	A	Demonstrate the ability to identify and explain the cl integrated circuits
AEIS – ET 58	B	A	A	Demonstrate the ability to identify and explain the cl binary number system
AEIS – ET 59	B	A	A	Demonstrate the ability to identify and explain the si symbols, their truth tables, and their logic expression

AEIS – ET 60	B	A	A	Demonstrate the ability to identify and explain the te relates to digital circuits
AEIS – ET 61	B	A	A	Demonstrate the ability to identify the logic diagram three basic types of "flip-flops"
AEIS – ET 62	B	A	A	Demonstrate the ability to identify and explain the c two most common types of sequential logic circuits
AEIS – ET 63	B	A	A	Demonstrate the ability to identify and explain the c simple microprocessors
AEIS – ET 64	**B**	**A**	**A**	**Demonstrate the ability to locate, identify ARNIC**
AEIS – ET 65	**B**	**B**	**A**	**Demonstrate the ability to explain ARNIC specifi and ARNIC 629**
AEIS – ET 66	**B**	**B**	**A**	**Demonstrate the ability to decode ARINC 429 Da and binary coded decimal word formats**
AEIS – ET 67	**B**	**B**	**A**	**Demonstrate the ability to explain data transmiss CSDB, ASCB, and MANCHESTER**

Maintenance Practices for Electrical Systems

SPO Item #	Student Performance Levels			Student Performance Objectiv
	Knowledge	Application	Manipulative Skills	
AEIS – MP 1	**C**	**B**	**A**	**Demonstrate the ability to locate and explain the Specification**
AEIS – MP 2	**C**	**C**	**A**	**Demonstrate the ability to read and interpret air schematic diagrams for single engine aircraft (Pt.**
AEIS – MP 3	**C**	**C**	**A**	**Demonstrate the ability to read and interpret air schematic diagrams for single engine aircraft (Pt. circuits**
AEIS – MP 4	**C**	**C**	**A**	**Demonstrate the ability to read and interpret air schematic diagrams for twin engine aircraft (Pt.**
AEIS – MP 5	**C**	**C**	**A**	**Demonstrate the ability to read and interpret air schematic diagrams for twin engine turboprop ai supply circuits**
				Demonstrate the ability to read and interpret aircraft

AEIS – MP 6	C	C	A	diagrams for twin engine turboprop aircraft (Pt. 23)
AEIS – MP 7	C	C	A	Demonstrate the ability to read and interpret aircraft diagrams for twin engine turboprop aircraft (Pt. 23) and indicating circuits
AEIS – MP 8	**C**	**C**	**A**	**Demonstrate the ability to read and interpret airc schematic diagrams for aircraft (Pt. 25) starting c**
AEIS – MP 9	**C**	**C**	**A**	**Demonstrate the ability to read and interpret airc schematic diagrams for aircraft (Pt. 25) single an distribution circuits**
AEIS – MP 10	**C**	**C**	**A**	**Demonstrate the ability to read and interpret airc schematic diagrams for aircraft (Pt. 25) interior c**
AEIS – MP 11	**C**	**C**	**A**	**Demonstrate the ability to read and interpret airc schematic diagrams for aircraft (Pt. 25) ground a circuits**
AEIS – MP 12	**C**	**C**	**A**	**Demonstrate the ability to read and interpret airc schematic diagrams for aircraft (Pt. 25) landing g indicating circuits**
AEIS – MP 13	C	C	C	Demonstrate the ability identify and use electrical ci digital and analog multi-meters, time delay reflector and data bus analyzer
AEIS – MP 14	B	B	A	Demonstrate the ability to locate and explain the pro Built-In-Test-Equipment and Central Maintenance C test and troubleshoot aircraft operational malfunctio under Part 25
AEIS – MP 15	C	C	C	Demonstrate the ability to troubleshoot electrical cir Short–to–Ground, By-Pass Shorts, and Added Resis
AEIS – MP 16	B	B	A	Demonstrate the ability to locate and explain manufa practices for repairing aircraft (Pt. 23) electrical syst
AEIS – MP 17	**C**	**B**	**A**	**Demonstrate the ability to locate and explain man carrier (Pt. 121) and FAA practices for repairing electrical systems**
AEIS – MP 18	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft wiring plugs, switches and protective devices**
AEIS – MP 19	**C**	**C**	**C**	**Demonstrate the ability to install aircraft wiring, protective devices**
AEIS – MP 20	**C**	**C**	**C**	**Demonstrate the ability to repair aircraft wiring splices and terminations**
AEIS – MP 21	**C**	**C**	**C**	**Demonstrate the ability to remove, install and tor electrical connector plugs; solder and pin replace**

AEIS – MP 22	C	C	C	Demonstrate the ability to select the proper size pins connector plugs both solder and pin replacement typ
AEIS – MP 23	C	C	C	Demonstrate the ability to remove and install variou on connector plugs both solder and pin replacement
AEIS – MP 24	B	B	B	Demonstrate the ability to inspect aircraft antennas
AEIS – MP 25	B	B	B	Demonstrate the ability to perform routine maintena antennas
AEIS – MP 26	C	C	B	Demonstrate the ability to inspect aircraft electronic installations and electronic equipment racks
AEIS – MP 27	B	B	B	Demonstrate the ability to perform routine maintena electronic equipment installations and electronic equ
AEIS – MP 28	**B**	**B**	**A**	**Demonstrate the ability to identify electro parts**
AEIS – MP 29	**C**	**B**	**A**	**Demonstrate the ability to locate and explain the proper handling and maintenance practices for e discharge-sensitive parts**

Electrical Power Generation Systems

SPO Item #	Student Performance Levels Knowledge	Application	Manipulative Skills	Student Performance Objectiv
AEIS – EP 1	**B**	**B**	**A**	**Demonstrate the ability to identify and explain th electrical power generation within aircraft lead**
AEIS – EP 2	**C**	**C**	**C**	**Demonstrate the ability to service and charge air batteries**
AEIS – EP 3	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft lead battery installations**
AEIS – EP 4	**C**	**C**	**C**	**Demonstrate the ability to perform routine maint acid batteries, batteries circuits, and battery insta**
AEIS – EP 5	**C**	**C**	**B**	**Demonstrate the ability to troubleshoot operation aircraft lead-acid battery circuits**
AEIS – EP 6	C	C	A	Demonstrate the ability to identify and explain the p power generation within aircraft Ni-Cad batteries

AEIS – EP 7	C	C	C	Demonstrate the ability to service and charge aircraf
AEIS – EP 8	C	C	C	Demonstrate the ability to inspect aircraft Ni installations
AEIS – EP 9	C	C	C	Demonstrate the ability to perform routine maintena batteries, batteries circuits, and battery installations
AEIS – EP 10	**C**	**C**	**B**	**Demonstrate the ability to troubleshoot operation aircraft Ni-Cad battery circuits**
AEIS – EP 11	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th components in an aircraft ground power circuit o under Part 25**
AEIS – EP 12	**B**	**A**	**A**	**Demonstrate the ability to locate and explain the procedures for ground power hook-up on aircraf 25**
AEIS – EP 13	**B**	**B**	**A**	**Demonstrate the ability to troubleshoot operation aircraft ground power circuits on aircraft certifi**
AEIS – EP 14	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th principles of aircraft DC generators, starter alternators**
AEIS – EP 15	B	B	B	Demonstrate the ability to inspect aircraft DC genera generators and alternators installations and circuits
AEIS – EP 16	B	B	B	Demonstrate the ability to perform routine maintena DC generators, starter-generators and alternators ins
AEIS – EP 17	B	B	B	Demonstrate the ability to troubleshoot operational r aircraft DC generators, starter-generators and alterna
AEIS – EP 18	B	A	A	Demonstrate the ability to identify and explain the o aircraft AC generators
AEIS – EP 19	B	B	B	Demonstrate the ability to inspect aircraft AC genera installations and generator circuits
AEIS – EP 20	**B**	**B**	**B**	**Demonstrate the ability to perform routine maint aircraft AC generators, generator installations ar**
AEIS – EP 21	**B**	**B**	**B**	**Demonstrate the ability to troubleshoot operation aircraft AC generators and generator circuits**
AEIS – EP 22	**B**	**B**	**A**	**Demonstrate the ability to identify and explain th principles of aircraft inverters, current transforn**
				Demonstrate the ability to inspect aircraft inverte

AEIS – EP 23	**B**	**B**	**B**	**transformers and rectifiers, their installation and**
AEIS – EP 24	**B**	**B**	**B**	**Demonstrate the ability to perform routine maint aircraft inverters and rectifiers, their installation**
AEIS – EP 25	B	A	A	Demonstrate the ability to identify and explain the o aircraft starters and motors
AEIS – EP 26	B	B	B	Demonstrate the ability to inspect aircraft electrical installation and circuits
AEIS – EP 27	B	B	B	Demonstrate the ability to perform routine maintena electrical motors, their installation and circuits
AEIS – EP 28	C	B	A	Demonstrate the ability to explain the principles of e distribution and load requirements for aircraft certifi 25
AEIS – EP 29	C	A	A	Demonstrate the ability to explain the operation of e distribution circuits for aircraft certified under part 2
AEIS – EP 30	C	B	B	Demonstrate the ability to troubleshoot operational r electrical power distribution system for aircraft certi 25
AEIS – EP 31	C	C	A	Demonstrate the ability to perform an electrical load

Communication, Navigation and Warning Systems

SPO Item #	Student Performance Levels Knowledge	Application	Manipulative Skills	Student Performance Objectiv
AEIS – CNW 1	**C**	**A**	**A**	**Demonstrate the ability to explain radio transmit principles of operation**
AEIS – CNW 2	**B**	**B**	**A**	**Demonstrate the ability to explain the operating p aircraft VHF communication system**
AEIS – CNW 3	**B**	**B**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft VHF communica**
AEIS – CNW 4	**B**	**B**	**B**	**Demonstrate the ability to locate and explain the ground testing an aircraft VHF communication s**
AEIS – CNW 5	**B**	**B**	**B**	**Demonstrate the ability to perform routine maint installation on aircraft VHF communication syste**

AEIS – CNW 6	B	C	B	Demonstrate the ability to troubleshoot operational r aircraft VHF communication systems
AEIS – CNW 7	B	A	A	Demonstrate the ability to explain the operating prin HF communication system
AEIS – CNW 8	B	A	A	Demonstrate the ability to identify and explain the p components in an aircraft HF communication system
AEIS – CNW 9	B	B	A	Demonstrate the ability to locate and explain the pro testing an aircraft HF communication system
AEIS – CNW 10	B	B	A	Demonstrate the ability to troubleshoot operational r aircraft HF communication systems
AEIS – CNW 11	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft SELCAL (Selective Calling) communica**
AEIS – CNW 12	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft SECAL (Selectiv communication system**
AEIS – CNW 13	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft SECAL (Selective Call system**
AEIS – CNW 14	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft ACARS (ARNIC Communication Addre System) communication system**
AEIS – CNW 15	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft ACARS (ARNIC Addressing and Reporting System) communicatio**
AEIS – CNW 16	B	B	A	Demonstrate the ability to locate and explain the pro testing an aircraft ACARS (ARNIC Communication Reporting System) communication system
AEIS – CNW 17	B	A	A	Demonstrate the ability to explain the operating prin Satellite communication system
AEIS – CNW 18	B	A	A	Demonstrate the ability to identify and explain the p components in an aircraft Satellite communication s
AEIS – CNW 19	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft interphones and passenger communicatio systems**
AEIS – CNW 20	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in a aircraft interphones and p communication and entertainment systems**
AEIS – CNW 21	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing a aircraft interphones and passeng**

				systems
AEIS – CNW 22	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft compass and attitude sensing systems fou certified under Part 25**
AEIS – CNW 23	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in a aircraft compass and attit found in aircraft certified under Part 25**
AEIS – CNW 24	B	B	A	Demonstrate the ability to locate and explain the pro testing a aircraft compass and attitude sensing syster certified under Part 25
AEIS – CNW 25	B	B	A	Demonstrate the ability to locate the technical inforn for performing routine maintenance tasks and repairs and attitude sensing systems found in aircraft certifie
AEIS – CNW 26	B	A	A	Demonstrate the ability to explain the operating prin Inertial Navigation system
AEIS – CNW 27	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft Inertial Navigati**
AEIS – CNW 28	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft Inertial Navigation sys**
AEIS – CNW 29	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft laser and conventional gyros**
AEIS – CNW 30	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft laser and conven**
AEIS – CNW 31	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft laser and conventional**
AEIS – CNW 32	B	A	A	Demonstrate the ability to explain the operating prin Automatic Direction Finder (ADF) system
AEIS – CNW 33	B	A	A	Demonstrate the ability to identify and explain the p components in an aircraft Automatic Direction Finde
AEIS – CNW 34	B	A	A	Demonstrate the ability to locate and explain the pro testing an aircraft Automatic Direction Finder (ADF
AEIS – CNW 35	B	B	A	Demonstrate the ability to explain the operating prin system found in aircraft
AEIS – CNW 36	B	A	A	Demonstrate the ability to identify and explain the p components in an LORAN system found in aircraft
AEIS – CNW 37	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an LORAN system found in aircra**

AEIS – CNW 38	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft VHF Navigation (VOR/ILS) system**
AEIS – CNW 39	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft VHF Navigation**
AEIS – CNW 40	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft VHF Navigation (VOR**
AEIS – CNW 41	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft Marker Beacon system**
AEIS – CNW 42	B	A	A	Demonstrate the ability to identify and explain the p components in an aircraft Marker Beacon system
AEIS – CNW 43	B	A	A	Demonstrate the ability to locate and explain the pro testing an aircraft Marker Beacon system
AEIS – CNW 44	B	A	A	Demonstrate the ability to explain the operating prin Distance Measuring Equipment (DME) system
AEIS – CNW 45	B	A	A	Demonstrate the ability to identify and explain the p components in an aircraft Distance Measuring Equip
AEIS – CNW 46	B	B	A	Demonstrate the ability to locate and explain the pro testing an aircraft Distance Measuring Equipment (D
AEIS – CNW 47	B	A	A	Demonstrate the ability to explain the operating prin Radio Altimeter system found in aircraft certified un
AEIS – CNW 48	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft Radio Altimeter aircraft certified under Part 25**
AEIS – CNW 49	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft Radio Altimeter systen certified under Part 25**
AEIS – CNW 50	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft Global Positioning System (GPS) found i**
AEIS – CNW 51	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft Global Positionii**
AEIS – CNW 52	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft Global Positioning Sys**
AEIS – CNW 53	B	A	A	Demonstrate the ability to explain the operating prin ATC Transponder system
				Demonstrate the ability to identify and explain the p

AEIS – CNW 54	B	A	A	components in an aircraft ATC Transponder system
AEIS – CNW 55	B	B	A	Demonstrate the ability to locate and explain the pro testing an aircraft ATC Transponder system
AEIS – CNW 56	B	A	A	Demonstrate the ability to explain the operating prin Weather Radar systems
AEIS – CNW 57	B	A	A	Demonstrate the ability to identify and explain the p components in an aircraft Weather Radar systems
AEIS – CNW 58	B	B	A	Demonstrate the ability to locate and explain the safe followed when working on and around radar system
AEIS – CNW 59	**B**	**A**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft Weather Radar system**
AEIS – CNW 60	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft Traffic Alert and Collision Avoidance Sy**
AEIS – CNW 61	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft Traffic Alert and System (TCAS)**
AEIS – CNW 62	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft Traffic Alert and Colli System (TCAS)**
AEIS – CNW 63	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft Windshear Warning Systems**
AEIS – CNW 64	B	A	A	Demonstrate the ability to identify and explain the p components in an aircraft Windshear Warning Syste
AEIS – CNW 65	B	A	A	Demonstrate the ability to locate and explain the pro testing an aircraft Windshear Warning Systems
AEIS – CNW 66	B	A	A	Demonstrate the ability to explain the operating prin Ground Proximity Warning Systems (GPWS) found under Part 25
AEIS – CNW 67	B	A	A	Demonstrate the ability to identify and explain the p components in an aircraft Ground Proximity Warnin found in aircraft certified under Part 25
AEIS – CNW 68	B	B	A	Demonstrate the ability to locate and explain the pro testing an aircraft Ground Proximity Warning Syster aircraft certified under Part 25
AEIS – CNW 69	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft Stall Warning Systems found in aircraft 25**
				Demonstrate the ability to identify and explain th

AEIS – CNW 70	**B**	**A**	**A**	**of the components in an aircraft Stall Warning Sy aircraft certified under Part 25**
AEIS – CNW 71	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing an aircraft Stall Warning Systems certified under Part 25**
AEIS – CNW 72	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft Flight Data and Cockpit Voice Recorder aircraft certified under Part 25**
AEIS – CNW 73	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft Flight Data and Recorder systems found in aircraft certified unde**
AEIS – CNW 74	B	A	A	Demonstrate the ability to locate and explain the pro testing an aircraft Flight Data and Cockpit Voice Re in aircraft certified under Part 25
AEIS – CNW 75	B	A	A	Demonstrate the ability to explain the operating prin Emergency Locator Transmitter (ELT) system
AEIS – CNW 76	B	A	A	Demonstrate the ability to identify and explain the p components in an Emergency Locator Transmitter (
AEIS – CNW 77	B	B	B	Demonstrate the ability to locate and explain the pro testing an Emergency Locator Transmitter (ELT) sys

Flight Management Systems

SPO Item #	Student Performance Levels Knowledge	Application	Manipulative Skills	Student Performance Objectiv
AEIS – FMS 1	**C**	**B**	**A**	**Demonstrate the ability to explain the principles o flight management system**
AEIS – FMS 2	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the components in an aircraft flight manageme**
AEIS – FMS 3	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th (inputs and outputs) in a flight management syste**
AEIS – FMS 4	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th available from the aircraft flight management sys**
AEIS – FMS 5	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th (message) function in the flight management syste**
				Demonstrate the ability to identify and explain the c management computer system

AEIS – FMS 6	B	A	A	
AEIS – FMS 7	B	B	A	Demonstrate the ability to locate and explain the pro testing the flight management computer system
AEIS – FMS 8	B	A	A	Demonstrate the ability to explain the principles of c management computer system
AEIS – FMS 9	B	A	A	Demonstrate the ability to identify and explain the p components in an air data computer system
AEIS – FMS 10	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th (inputs and outputs) in a air data computer syste**
AEIS – FMS 11	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th data computer system**
AEIS – FMS 12	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the ground testing the air data computer system**
AEIS – FMS 13	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p electronic display systems (EFIS, EIS,**
AEIS – FMS 14	**B**	**A**	**A**	**Demonstrate the ability to locate and identify line (LRU) in electronic display systems (EFIS, EIS, I**
AEIS – FMS 15	B	B	A	Demonstrate the ability to locate and explain the pro installing line replaceable units (LRU)and ground te proper operation in electronic display systems (EFIS
AEIS – FMS 16	B	A	A	Demonstrate the ability to explain the operating prin Indicating and Crew Alerting Systems (EICAS) and Centralized Aircraft Monitoring System (ECAM)
AEIS – FMS 17	**B**	**B**	**A**	**Demonstrate the ability to locate and identify line (LRU) in Engine Indicating and Crew Alerting Sy Electronic Centralized Aircraft Monitoring Syste**
AEIS – FMS 18	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the removing and installing line replaceable units (LI testing the system for proper operation in Engine Alerting Systems (EICAS) and Electronic Centra Monitoring System (ECAM)**
AEIS – FMS 19	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p gyroscopes (conventional and laser) as the relate instruments**
AEIS – FMS 20	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p transmitters and receivers**
AEIS – FMS 21	**B**	**A**	**A**	**Demonstrate the ability to explain the operating p and Linear Variable Differential Transformers (I**

AEIS – FMS 22	B	A	A	Demonstrate the ability to explain the principles of o Autoflight Control System in aircraft certified under
AEIS – FMS 23	B	A	A	Demonstrate the ability to identify the primary and s functions for an Autoflight Control System certified
AEIS – FMS 24	B	A	A	Demonstrate the ability to identify and explain the p primary units in an Autoflight Control System for ar under Pt. 23 and 25
AEIS – FMS 25	**B**	**A**	**A**	**Demonstrate the ability to explain the function ar operation for the Yaw Damper System in an Auto System in aircraft certified under Pt. 25**
AEIS – FMS 26	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the primary units in the Yaw Damper System i Control System for an aircraft certified under Pt.**
AEIS – FMS 27	**B**	**A**	**A**	**Demonstrate the ability to explain the function ar operation for the Thrust Management System in Control System in aircraft certified under Pt. 25**
AEIS – FMS 28	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the primary units in the Thrust Management S Autoflight Control System for an aircraft certifie**
AEIS – FMS 29	**B**	**A**	**A**	**Demonstrate the ability to explain the function ar operation for the Autopilot Flight Director Syster Control System in aircraft certified under Pt. 25**
AEIS – FMS 30	B	A	A	Demonstrate the ability to identify and explain the p primary units in the Autopilot Flight Director Syster Control System for an aircraft certified under Pt. 25
AEIS – FMS 31	**B**	**A**	**A**	**Demonstrate the ability to explain the function ar operation for the Auto Stabilization Trim and Ma Systems in an Autoflight Control System in aircra 25**
AEIS – FMS 32	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the primary units in the Auto Stabilization Tri Stability system in an Autoflight Control System certified under Pt. 25**
AEIS – FMS 33	**B**	**A**	**A**	**Demonstrate the ability to explain the function ar operation for the Maintenance Monitor Systems i Control System in aircraft certified under Pt. 25**
AEIS – FMS 34	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th of the primary units in the Maintenance Monitor Autoflight Control System for an aircraft certifie**
AEIS – FMS 35	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th controls in an Autoflight Control System in aircra 25**
				Demonstrate the ability to identify and explain the ar warnings used in an Autoflight Control System for a

AEIS – FMS 36	B	A	A	under Pt. 25
AEIS – FMS 37	**B**	**B**	**A**	**Demonstrate the ability to locate and explain the troubleshooting faults in an Autoflight Control Sy certified under Pt. 25**
AEIS – FMS 38	**B**	**A**	**A**	**Demonstrate the ability to locate and explain the removing and installing line replaceable units (LI testing the system for proper operation in an Aut System for aircraft certified under Pt. 25**
AEIS – FMS 39	**B**	**A**	**A**	**Demonstrate the ability to state and explain the c for law engagement for fly-by-wire control systen**
AEIS – FMS 40	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th function of servos and actuators used in autoiligh certified under Pt. 25**
AEIS – FMS 41	**B**	**A**	**A**	**Demonstrate the ability to explain the principles In Test Equipment Systems (BITE)**
AEIS – FMS 42	B	A	A	Demonstrate the ability to locate and explain the ope Built In Test Equipment (BITE)
AEIS – FMS 43	B	A	A	Demonstrate the ability to explain the principles of c Maintenance Computer Systems (CMC)
AEIS – FMS 44	B	A	A	Demonstrate the ability to locate and explain the ope Central Maintenance Computers (CMC)

Aircraft Systems

SPO Item #	Student Performance Levels			Student Performance Objectiv
	Knowledge	Application	Manipulative Skills	
ASYS 1	**C**	**A**	**A**	**Demonstrate the ability to identify and explain th dynamics as they relate to aircraft hydraulic syste**
ASYS 2	**C**	**B**	**A**	**Demonstrate the ability to explain the operation c systems used on aircraft certified under Part 23 a**
ASYS 3	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th of aircraft hydraulic system components used on under Part 23 and 25**
ASYS 4	**C**	**C**	**A**	**Demonstrate the ability to identify and select flui hydraulic systems**

ASYS 5	**C**	**C**	**C**	**Demonstrate the ability to service aircraft hydrau**
ASYS 6	C	C	C	Demonstrate the ability to inspect aircraft hydraulic components
ASYS 7	C	C	B	Demonstrate the ability to perform routine maintena on aircraft hydraulic systems and system component
ASYS 8	C	C	B	Demonstrate the ability to troubleshoot operational r aircraft hydraulic systems and system components
ASYS 9	B	A	A	Demonstrate the ability to explain the operation of ty systems found on aircraft certified under Part 25
ASYS 10	B	A	B	Demonstrate the ability to identify and explain the p aircraft pneumatic system components
ASYS 11	**C**	**B**	**A**	**Demonstrate the ability to explain the operation o gear systems used on aircraft certified under Par**
ASYS 12	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th of aircraft landing gear system components**
ASYS13	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft landin system components**
ASYS 14	**C**	**C**	**C**	**Demonstrate the ability to perform routine maint repairs on aircraft landing gear systems and syste**
ASYS 15	**C**	**C**	**C**	**Demonstrate the ability to troubleshoot operation aircraft landing gear systems and system compon**
ASYS 16	C	B	A	Demonstrate the ability to explain the operation of ty indicating systems used on aircraft certified under Pa
ASYS 17	C	C	C	Demonstrate the ability to inspect aircraft landing ge
ASYS 18	C	C	C	Demonstrate the ability to perform routine maintena on aircraft landing gear indicating systems
ASYS 19	C	C	C	Demonstrate the ability to troubleshoot operational r aircraft landing gear indicating systems
ASYS 20	C	C	A	Demonstrate the ability to locate and explain the pro precautions for jacking aircraft
ASYS 21	C	B	A	Demonstrate the ability to locate and explain special precautions for jacking aircraft certified under Pt. 25

ASYS 22	C	C	C	Demonstrate the ability to raise an aircraft using airc
ASYS 23	**C**	**B**	**A**	**Demonstrate the ability to explain the operation o anti-skid systems used on aircraft certified under**
ASYS 24	**C**	**A**	**A**	**Demonstrate the ability to identify and explain th of aircraft brake and anti-skid system component**
ASYS 25	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft brake systems and system components**
ASYS 26	**C**	**C**	**C**	**Demonstrate the ability to perform routine maint repairs on aircraft brake and anti-skid systems ar components**
ASYS 27	**C**	**C**	**B**	**Demonstrate the ability to troubleshoot operation aircraft brake and anti-skid systems and system c**
ASYS 28	C	A	A	Demonstrate the ability to explain the operation of ty used on aircraft certified under Part 23 and 25
ASYS 29	C	B	A	Demonstrate the ability to identify and explain the p aircraft steering system components
ASYS 30	C	C	C	Demonstrate the ability to inspect aircraft steering sy components
ASYS 31	C	C	C	Demonstrate the ability to perform routine maintena on aircraft steering systems and system components
ASYS 32	C	C	B	Demonstrate the ability to troubleshoot operational r aircraft steering systems and system components
ASYS 33	C	C	C	Demonstrate the ability to inspect aircraft wheels anc
ASYS 34	**C**	**C**	**C**	**Demonstrate the ability to perform routine maint repairs on aircraft wheels and tires**
ASYS 35	**C**	**C**	**C**	**Demonstrate the ability to troubleshoot operation aircraft tires**
ASYS 36	**C**	**A**	**A**	**Demonstrate the ability to explain the operation o used on aircraft certified under Part 23 and 25**
ASYS 37	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th of aircraft fuel system components used on aircra Part 23 and 25**
ASYS 38	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft fuel sy components**
				Demonstrate the ability to perform routine maintena

ASYS 39	C	C	C	on aircraft fuel systems and system components
ASYS 40	C	C	C	Demonstrate the ability to troubleshoot operational r aircraft fuel systems and system components
ASYS 41	C	A	A	Demonstrate the ability to explain the operation of ty indicating systems used on aircraft certified under Pa
ASYS 42	C	C	C	Demonstrate the ability to inspect aircraft fuel quant
ASYS 43	C	C	C	Demonstrate the ability to perform routine maintena on aircraft fuel quantity indicating systems
ASYS 44	C	C	C	Demonstrate the ability to troubleshoot operational r aircraft fuel quantity indicating systems
ASYS 45	C	B	A	Demonstrate the ability locate and explain to proced aircraft fuel quantity indicating systems
ASYS 46	**C**	**A**	**A**	**Demonstrate the ability to explain the operation o systems, including transfer and dump operations under Part 25**
ASYS 47	**C**	**A**	**A**	**Demonstrate the ability to explain the operation o temperature indicating systems used on aircraft c 23 and 25**
ASYS 48	**C**	**C**	**C**	**Demonstrate the ability to perform routine maint repairs on aircraft fuel pressure and temperature**
ASYS 49	**C**	**C**	**C**	**Demonstrate the ability to troubleshoot operation aircraft fuel pressure and temperature indicating**
ASYS 50	**C**	**A**	**A**	**Demonstrate the ability to locate and explain the management systems, including transfer and dum aircraft certified under Part 25**
ASYS 51	C	A	A	Demonstrate the ability to explain the operation of f temperature indicating systems on aircraft certified u
ASYS 52	C	A	A	Demonstrate the ability to explain the operation of p systems on aircraft certified under Part 25
ASYS 53	B	A	A	Demonstrate the ability to locate the inspection proc fueling systems on aircraft certified under Part 25
ASYS 54	B	A	A	Demonstrate the ability to locate and explain the pro performing routine maintenance tasks and repairs on fueling systems on aircraft certified under Part 25
ASYS 55	C	A	A	Demonstrate the ability to explain the operation of ty found on aircraft certified under Part 23 and 25

ASYS 56	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th of aircraft heating system components**
ASYS 57	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft heatin components**
ASYS 58	**C**	**C**	**C**	**Demonstrate the ability to perform routine maint repairs on aircraft heating systems and system co**
ASYS 59	**C**	**C**	**C**	**Demonstrate the ability to troubleshoot operation aircraft heating systems and system components**
ASYS 60	**C**	**A**	**A**	**Demonstrate the ability to explain the operation c conditioning systems found on aircraft certified u**
ASYS 61	C	B	A	Demonstrate the ability to identify and explain the p aircraft air conditioning system components
ASYS 62	C	C	C	Demonstrate the ability to inspect aircraft air conditi system components
ASYS 63	C	B	A	Demonstrate the ability to perform routine maintena on aircraft air conditioning systems and system com
ASYS 64	C	B	B	Demonstrate the ability to troubleshoot operational r aircraft air conditioning systems and system compo
ASYS 65	C	A	A	Demonstrate the ability to explain the operation of ty systems found on aircraft certified under Part 23 and
ASYS 66	C	B	A	Demonstrate the ability to identify and explain the p aircraft pressurization system components
ASYS 67	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft pressu system components**
ASYS 68	**C**	**B**	**B**	**Demonstrate the ability to perform routine maint repairs on aircraft pressurization systems and sys**
ASYS 69	**C**	**B**	**B**	**Demonstrate the ability to troubleshoot operation aircraft pressurization systems and system comp**
ASYS 70	**C**	**A**	**A**	**Demonstrate the ability to explain the operation c systems found on aircraft certified under Part 23**
ASYS 71	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th of aircraft oxygen system components**
				Demonstrate the ability to inspect aircraft oxygen sy

ASYS 72	C	C	C	components
ASYS 73	C	B	B	Demonstrate the ability to perform routine maintena on aircraft oxygen systems and system components
ASYS 74	C	B	B	Demonstrate the ability to troubleshoot operational r aircraft oxygen systems and system components
ASYS 75	C	C	A	Demonstrate the ability to locate the information for procedures for proper handling and disposal of aircra generators
ASYS 76	C	A	A	Demonstrate the ability to explain the operation of ty control systems found on aircraft certified under Par
ASYS 77	C	B	A	Demonstrate the ability to identify and explain the p aircraft ice and rain control system components
ASYS 78	C	C	C	Demonstrate the ability to inspect aircraft ice and rai system components
ASYS 79	**C**	**B**	**B**	**Demonstrate the ability to perform routine maint repairs on aircraft ice and rain control systems ar components**
ASYS 80	**C**	**B**	**B**	**Demonstrate the ability to troubleshoot operation aircraft ice and rain control systems and system**
ASYS 81	**C**	**A**	**A**	**Demonstrate the ability to explain the operation o detection and extinguishing systems(airframe anc aircraft certified under Part 23 and 25**
ASYS 82	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th of aircraft and engine fire detection and extinguis components**
ASYS 83	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft and en and extinguishing systems and system component**
ASYS 84	C	B	B	Demonstrate the ability to perform routine maintena on aircraft and engine fire detection and extinguishin components
ASYS 85	C	B	B	Demonstrate the ability to troubleshoot operational r aircraft and engine fire detection and extinguishing s components
ASYS 86	C	A	A	Demonstrate the ability to explain the operation of ty carbon monoxide systems found on aircraft certified
ASYS 87	C	C	C	Demonstrate the ability to inspect aircraft smoke anc detection systems
				Demonstrate the ability to perform routine maint

ASYS 88	**C**	**B**	**B**	**repairs on aircraft smoke and carbon monoxide s components**
ASYS 89	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th instruments used with aircraft reciprocating engi**
ASYS 90	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th instruments used with aircraft turbine engines**
ASYS 91	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th flight instruments used in aircraft certified under**
ASYS 92	**B**	**A**	**A**	**Demonstrate the ability to identify and explain th flight instruments used in aircraft certified under**
ASYS 93	B	A	A	Demonstrate the ability to identify and explain the fu navigation instruments used in aircraft certified unde
ASYS 94	B	A	A	Demonstrate the ability to identify and explain the fu navigation instruments used in aircraft certified unde
ASYS 95	B	A	A	Demonstrate the ability to identify and explain the fu system instruments used in aircraft certified under P
ASYS 96	B	A	A	Demonstrate the ability to identify and explain the fu system instruments used in aircraft certified under P
ASYS 97	B	A	A	Demonstrate the ability to explain the operation of a and temperature measuring instrument systems
ASYS 98	B	A	A	Demonstrate the ability to explain the operation of a measuring instrument systems
ASYS 99	B	A	A	Demonstrate the ability to explain the operation of a and static system
ASYS 100	**C**	**C**	**C**	**Demonstrate the ability to perform pitot and stat**
ASYS 101	**B**	**B**	**B**	**Demonstrate the ability to perform routine maint repairs on aircraft and engine instruments and in**
ASYS 102	**B**	**B**	**A**	**Demonstrate the ability to locate instrument mar**
ASYS 103	**C**	**A**	**A**	**Demonstrate the ability to explain the operating p aircraft compass system found in aircraft certifie**
ASYS 104	**B**	**A**	**A**	**Demonstrate the ability to perform routine maint repairs to aircraft compass systems found in airc Part 23**
ASYS 105	C	B	B	Demonstrate the ability to swing an aircraft compass

Aircraft Structures

SPO Item #	Student Performance Levels Knowledge	Application	Manipulative Skills	Student Performance Objectiv
ASTR 1	**A**	**A**	**A**	**Demonstrate the ability to locate and explain the procedures and practices for aircraft wood struct**
ASTR 2	**A**	**A**	**A**	**Demonstrate the ability to locate and explain the procedures and practices for aircraft fabric cove**
ASTR 3	**A**	**A**	**A**	**Demonstrate the ability to locate and explain the welding and brazing aluminum and steel aircraft**
ASTR 4	**C**	**C**	**A**	**Demonstrate the ability to identify and select met aircraft using manufactures and air carrier tech material designation symbols**
ASTR 5	**C**	**C**	**C**	**Demonstrate the ability to identify, properly use and machines used in aircraft sheet metal structu**
ASTR 6	C	C	A	Demonstrate the ability to identify, select and detern substitute fasteners for aircraft sheet metal repairs
ASTR 7	C	C	C	Demonstrate the ability to identify and install aircra
ASTR 8	C	C	C	Demonstrate the ability to identify and install Dzus, fasteners
ASTR 9	C	C	C	Demonstrate the ability to properly drill holes in air installation
ASTR 10	**B**	**B**	**B**	**Demonstrate the ability to properly inspect holes metal structures, where rivets have been remove** processes
ASTR 11	C	C	C	Demonstrate the ability to install and remove solid r and flush) in aluminum sheet of thickness from .020
ASTR 12	C	C	C	Demonstrate the ability to shave flush head solid riv technical specifications
ASTR 13	C	C	C	Demonstrate the ability to install and remove blind r
ASTR 14	C	C	C	Demonstrate the ability to machine and hand form a includes the following processes; bending, joggles, s bumping, flanging lighting holes, dimpling}

ASTR 15	C	C	C	Demonstrate the ability to layout patterns on alumin
ASTR 16	C	C	C	Demonstrate the ability to manufacture a part using blueprints or drawings
ASTR 17	C	B	A	Demonstrate the ability to locate and explain the ma carrier(Pt. 121) technical data for the classification c structural damage
ASTR 18	C	B	A	Demonstrate the ability to properly identify and clas metal structural damage
ASTR 19	C	B	A	Demonstrate the ability to locate and explain manufa (Pt. 121) technical data for approving an aircraft she repair
ASTR 20	C	C	C	Demonstrate the ability to layout a repair for aircraft
ASTR 21	C	C	C	Demonstrate the ability to repair damaged aircraft m
ASTR 22	C	C	C	Demonstrate the ability to repair damaged aircraft m
ASTR 23	**C**	**C**	**C**	**Demonstrate the ability to repair damaged aircra**
ASTR 24	**C**	**C**	**C**	**Demonstrate the ability to repair damaged aircra leading edges**
ASTR 25	**C**	**C**	**C**	**Demonstrate the ability to repair damaged aircra trailing edges**
ASTR 26	**C**	**C**	**C**	**Demonstrate the ability to repair damaged aircra**
ASTR 27	**C**	**C**	**C**	**Demonstrate the ability to repair damaged aircra sandwich structures**
ASTR 28	C	C	C	Demonstrate the ability to properly protect aircraft n structural components from corrosion
ASTR 29	C	C	C	Demonstrate the ability to remove and treat corrosio surfaces and structural components using mechanica methods
ASTR 30	B	B	B	Demonstrate the ability to apply paint to aircraft me
ASTR 31	B	A	A	Demonstrate the ability to identify and explain the p working, shoot peening, roto peening and heat treati
ASTR 32	B	B	A	Demonstrate the ability to identify and select compo sealents, adhesives, and compounds for use on aircra manufactures and air carrier(Pt. 121) technical data a designation symbols

ASTR 33	C	C	C	Demonstrate the ability to identify, properly use and equipment used in aircraft composite structures mai
ASTR 34	**C**	**C**	**A**	**Demonstrate the ability to locate and explain the procedures for the use, handling and storing airc materials, sealant, adhesives, and compounds**
ASTR 35	**C**	**B**	**A**	**Demonstrate the ability to locate and explain the air carrier (Pt. 121) technical data for the classifi composite structural damage**
ASTR 36	**C**	**B**	**A**	**Demonstrate the ability to properly identify and composite structural damage**
ASTR 37	**C**	**B**	**A**	**Demonstrate the ability to locate and explain ma carrier (Pt. 121) technical data for approving an structural repair**
ASTR 38	**C**	**C**	**C**	**Demonstrate the ability to layout a repair for air structural damage**
ASTR 39	B	B	B	Demonstrate the ability to inspect aircraft composite components using visual and NDI techniques
ASTR 40	C	C	C	Demonstrate the ability to identify, select and deter substitute fasteners for aircraft composite structures
ASTR 41	C	C	C	Demonstrate the ability to make repairs to aircraft c using hot bonding equipment
ASTR 42	C	C	C	Demonstrate the ability to repair damaged aircraft la skin structure (access to only one side of the repair)
ASTR 43	C	C	C	Demonstrate the ability to repair damaged aircraft la skin structure (access to both sides of the repair)
ASTR 44	**C**	**C**	**C**	**Demonstrate the ability to repair cosmetic dama composite structure**
ASTR 45	**C**	**C**	**C**	**Demonstrate the ability to repair damage to an a structure requiring honeycomb core material rep**
ASTR 46	**C**	**C**	**C**	**Demonstrate the ability to repair damaged aircra leading edges**
ASTR 47	**C**	**C**	**C**	**Demonstrate the ability to repair damaged aircra trailing edges**
ASTR 48	**C**	**C**	**C**	**Demonstrate the ability to repair delamination d composite structure**
				Demonstrate the ability to repair loose and missing

ASTR 49	C	C	C	structures
ASTR 50	C	C	C	Demonstrate the ability to properly drill holes in airc structures
ASTR 51	C	C	C	Demonstrate the ability to inspect aircraft windows a
ASTR 52	C	B	A	Demonstrate the ability to locate and explain manufa (Pt. 121) technical data for repairing aircraft window
ASTR 53	C	C	C	Demonstrate the ability to remove minor scratches f windows
ASTR 54	C	C	C	Demonstrate the ability to inspect aircraft interior fu
ASTR 55	C	C	C	Demonstrate the ability to perform routine maintena on aircraft interior furnishings
ASTR 56	**C**	**B**	**A**	**Demonstrate the ability to identify and explain th aircraft primary and secondary flight control on under Part 23 and 25**
ASTR 57	**C**	**A**	**A**	**Demonstrate the ability to locate and explain the practices for rigging an aircraft certified under P**
ASTR 58	**C**	**C**	**C**	**Demonstrate the ability to inspect aircraft prima flight control systems**
ASTR 59	**C**	**C**	**C**	**Demonstrate the ability to clean and protect from flight control cables**
ASTR 60	**C**	**C**	**C**	**Demonstrate the ability to lubricate aircraft prim flight controls**
ASTR 61	C	C	C	Demonstrate the ability to rig an aircraft primary and controls
ASTR 62	C	C	C	Demonstrate the ability to check the alignment of ai structures
ASTR 63	C	C	C	Demonstrate the ability to remove, balance and reins primary and secondary control surfaces
ASTR 64	C	A	A	Demonstrate the ability to locate and explain the pro primary and secondary control surfaces on aircraft c
ASTR 65	C	A	A	Demonstrate the ability to locate and explain the pro doors on aircraft certified under Part 25
ASTR 66	C	C	C	Demonstrate the ability to rig aircraft doors for closu

ASTR 67	**B**	**A**	**A**	**Demonstrate the ability to locate and explain the inspecting speed and configuration warning syste certified under Pt. 25**
ASTR 68	**B**	**A**	**A**	**Demonstrate the ability to locate and explain the ground testing speed and configuration warning s certified under Pt. 25**
ASTR 69	**C**	**B**	**B**	**Demonstrate the ability to locate and explain the rigging helicopter main and tail rotors**
ASTR 70	**C**	**B**	**A**	**Demonstrate the ability to locate and explain the tracking helicopter main and tail rotors**

Aircraft Inspections and Capstone SPO's

SPO Item #	**Student Performance Levels**			**Student Performance Objecti**
	Knowledge	**Application**	**Manipulative Skills**	
AIC 1	**C**	**C**	**A**	**Demonstrate the ability to locate and explain the requirements for aircraft operating under Part 9**
AIC 2	**C**	**C**	**A**	**Demonstrate the ability to locate and explain the requirements for aircraft operating under Part 1**
AIC 3	**C**	**C**	**C**	**Demonstrate the ability to perform 100 hour airf inspections**
AIC 4	**C**	**C**	**C**	**Demonstrate the ability to document completed i records for aircraft operating under Part 91**
AIC 5	**C**	**C**	**C**	**Demonstrate the ability to document completed i records for aircraft operating under Part 121**
AIC 6	C	C	C	Demonstrate the ability to determine the status of Ai on aircraft and engines
AIC 7	C	C	C	Demonstrate the ability to perform a maintenance ta information provided in a typical air carrier (Pt. 121
				CAPSTONE STUDENT PERFORMANCE OBJE (S)

7.16 APPENDIX B
14 CFR Federal Aviation Regulation Part 147

PART 147-AVIATION MAINTENANCE TECHNICIAN SCHOOLS

Subpart A-General

147.1 Applicability.

This part prescribes the requirements for issuing aviation maintenance technician school certificates and associated ratings and the general operating rules for the holders of those certificates and ratings.

147.3 Certificate required.

No person may operate as a certificated aviation maintenance technician school without, or in violation of, an aviation maintenance technician school certificate issued under this part.

147.5 Application and issue.

(a) An application for a certificate and rating, or for an additional rating, under this part is made on a form and in a manner prescribed by the administrator, and submitted with-

(1) A description of the proposed curriculum;

(2) A list of the facilities and materials to be used;

(3) A list of its instructors, including the kind of certificate and ratings held and the certificate numbers;

(4) A statement of the maximum number of students it expects to teach at any one time.

(b) An applicant who meets the requirements of this part is entitled to an aviation maintenance technician school certificate and associated ratings prescribing such operations specifications and limitations as are necessary in the interests of safety.

147.7 Duration of certificates.

(a) An aviation maintenance technician school certificate or rating is effective until it is surrendered, suspended, or revoked.

(b) The holder of a certificate that is surrendered, suspended, or revoked, shall return it to the administrator.

Subpart B-Certification Requirements

147.11 Ratings.

The following ratings are issued under this part

(a) Airframe.

(b) Powerplant.

(c) Airframe and Powerplant.

147.13 Facilities, equipment, and material requirements.

An applicant for an aviation maintenance technician school certificate and rating, or for an additional rating, must have at least the facilities, equipment, and materials specified in 147.15 to 147.19 that are appropriate to the rating he seeks.

147.15 Space requirements.

An applicant for an aviation maintenance technician school certificate and rating, or for an additional rating, must have such of the following properly heated, lighted, and ventilated facilities as are appropriate to the rating he seeks and as the administrator determines are appropriate for the maximum number of students expected to be taught at any time:

(a) An enclosed classroom suitable for teaching theory classes.

(b) Suitable facilities, either central or located in training areas, arranged to assure proper separation from the working space, for parts, tools, materials, and similar articles.

(c) Suitable area for application of finishing materials, including paint spraying.

(d) Suitable areas equipped with washtank and degreasing equipment with air pressure, or other adequate cleaning equipment.

(e) Suitable facilities for running engines.

(f) Suitable area with adequate equipment, including benches, tables, and test equipment, to disassemble, service, and inspect.

(1) Ignition, electrical equipment, and appliances;

(2) Carburetors and fuel systems; and

(3) Hydraulic and vacuum systems for aircraft, aircraft engines, and their appliances.

(g) Suitable space, with adequate equipment including tables, benches, stands, and jacks, for disassembling, inspecting, and rigging aircraft.

(h) Suitable space, with adequate equipment, for disassembling, inspecting, assembling, troubleshooting, and timing engines.

147.17 Instructional equipment requirements.

(a) An applicant for a mechanic school certificate and rating, or for an additional rating, must have what of the following instructional equipment as is appropriate to the rating he seeks:

(1) Various kinds of airframe structures, airframe systems and components, powerplants, and powerplant systems and components (including propellers), of a quantity and type suitable to complete the practical projects required by its approved curriculums.

(2) At least one aircraft of a type currently certificated by FAA for private or commercial operation, with powerplant, propeller, instruments, navigation and communications equipment, landing lights, and other equipment and accessories on which a maintenance technician might be required to work and with which he should be familiar.

(b) The equipment required by paragraph (a) of this section need not be in an airworthy condition. However, if it was damaged, it must have been repaired enough for complete assembly.

(c) Airframes, powerplants, propellers, appliances, and components thereof, on which instruction is to be given, and from which practical working experience is to be gained, must be so diversified as to show the different methods of construction, assembly, inspection, and operation when installed in an aircraft for use. There must be enough units so that not more than eight students will work on any one unit at a time.

(d) If the aircraft used for instructional purposes does not have retractable landing gear and wing flaps, the school must provide training aids, or operational mock-ups of them.

147.19 Material, tool, and shop equipment requirements.

An applicant for an aviation maintenance technician school certificate and rating, or for an additional rating, must have an adequate supply of material, special tools, and such of the shop equipment, as are appropriate to the approved curriculum of the school and are used in constructing and maintaining aircraft, to assure that each student will be properly instructed. The special tools and shop equipment must be in satisfactory working condition for the purpose for which they are to be used.

147.21 General curriculum requirements.

(a) An applicant for an aviation maintenance technician school certificate and rating, or for an additional rating, must have an approved curriculum that is designed to qualify his students to perform the duties of a mechanic for a particular rating for ratings.

(b) The curriculum must offer at least the following number of hours of instruction for the rating shown, and the instruction unit hour shall not be less than 50 minutes in length—

(1) Airframe-1,150 hours (400 general plus 750 airframe).

(2) Powerplant-1,150 hours (400 general plus 750 powerplant).

(3) Combined airframe and powerplant-1,900 hours (400 general plus 750 airframe and 750 powerplant).

(c) The curriculum must cover the subjects and items prescribed in Appendix B, C or D as applicable.

(d) The curriculum must show-

(1) The required practical projects to be completed;

(2) For each subject, the proportions of theory and other instruction to be given; and

(3) A list of the minimum required school tests to be given.

(e) Notwithstanding the provisions of paragraphs (a) through (d) of this section and 147.11, the holder of a certificate issued under subpart B of this part may apply for and receive approval of special courses in the performance of special inspection and preventive maintenance programs for a primary category aircraft type certificated under 21,24(b) of this chapter. The school may also issue certificates of competency to persons successfully completing such courses provided that all other requirements of this part are met and the certificate of competency specifies the aircraft make and model to which the certificate applies.

147.23 Instructor requirements.

An applicant for an aviation maintenance technician school certificate and rating, or for an additional rating, must provide the number of instructors holding appropriate mechanic certificates and ratings that the administrator determines necessary to provide adequate instruction and supervision of the students, including at least one such instructor for each 25 students in each shop or laboratory class. However, the applicant may provide specialized instructors, who are not certificated mechanics, to teach only mathematics, physics, basic electricity, basic hydraulics, drawing, and similar subjects. The applicant is required to maintain a list of the names and qualifications of specialized instructors, and upon request, provide a copy of the list to the FAA.

147.31 Attendance and enrollment, tests, and credit for prior instruction or experience.

(a) A certificated aviation maintenance technician school may not require any student to attend classes of instruction more than eight hours in any day or more than six days or 40 hours in any seven-day period.

(b) Each school shall give an appropriate test to each student who completes a unit of instruction as shown in that school's approved curriculum.

(c) A school may not graduate a student unless he has completed all of the appropriate curriculum requirements. However, the school may credit a student with instruction or previous experience as follows:

(1) A school may credit a student with instruction satisfactorily completed at-

(i) An accredited university, college, junior college;

(ii) An accredited vocational, technical, trade or high school;

(iii) A military technical school;

(2) A school may determine the amount of credit to be allowed-

(i) By an entrance test equal to one given to the students who complete a comparable required curriculum subject at the crediting school;

(ii) By an evaluation of an authenticated transcript from the student's former school; or

(iii) In the case of an applicant from a military school, only on the basis of an entrance test.

(3) A school may credit a student with previous aviation maintenance experience comparable to required curriculum subjects. It must determine the amount of credit to be allowed by documents verifying that experience, and by giving the student a test equal to the one given to students who compete the comparable required curriculum subject at the school.

(4) A school may credit a student seeking an additional rating with previous satisfactory completion of the general portion of an AMTS curriculum.

(d) A school may not have more students enrolled than the number stated in its application for a certificate, unless it amends its application and has it approved.

(e) A school shall use an approved system for determining final course grades, and for recording student attendance. The system must show hours of absence allowed, and show how the missed material will be made available to the student.

147.33 Records

(a) Each certificated aviation maintenance technician school shall keep a current record of each student enrolled, showing-

(1) His attendance, tests, and grades received on the subjects required by this part;

(2) The instruction credited to him under 147.31(c), if any; and

(3) The authenticated transcript of his grades from that school.

It shall retain the record for at least two years after the end of the student's enrollment, and shall make each record available for inspection by the administrator during that period.

(b) Each school shall keep a current progress chart or individual progress record for each of its students showing the practical projects or laboratory work completed, or to be completed, by the student in each subject.

147.35 Transcripts and graduation certificates.

(a) Upon request, each certificated aviation maintenance technician school shall give a transcript of the student's grades to each student who is graduated from that school or who leaves it before being graduated. An official of the school shall authenticate the transcript. The transcript must state the curriculum and courses in which the student was enrolled, whether the student satisfactorily completed that curriculum and the final grades the student received.

(b) Each school shall give a graduation certificate or certificate of completion to each student that it graduates. An official of the school shall authenticate the certificate. The certificate must show the date of graduation and the approved curriculum title.

147.36 maintenance of instructor requirements.

Each certificated aviation maintenance technician school shall, after certification or addition of a rating, continue to provide the number of instructors holding appropriate mechanic certificates and ratings that the administrator determines necessary to provide adequate instruction to the students, including at least one such instructor for each 25 students in each shop class. The school may continue to provide specialized instructors, who are not certificated mechanics, to teach mathematics, physics, drawing, basic electricity, basic hydraulics, and similar subjects.

147.37 Maintenance of facilities, equipment, and material.

(a) Each certificated aviation maintenance technician school shall adhere to its approved curriculum. With FAA approval, curriculum subjects may be taught at levels exceeding those shown in Appendix A of this part.

(b) A school may not make a substantial change in facilities, equipment, or material that have been approved for a particular curriculum, unless that change is approved in advance.

147.38 Maintenance of curriculum requirements.

(a) Each certificated aviation maintenance technician school shall adhere to its approved curriculum. With FAA approval, curriculum subjects may be taught at levels exceeding those shown in Appendix A of this part.

(b) A school may not change its approved curriculum unless the change is approved in advance.

147.38a Quality of instruction.

Each certificated aviation maintenance technician school shall provide instruction of such quality that, of its graduates of a curriculum for each rating who apply for a mechanic certificate or additional rating within 60 days after they are graduated, the percentage of those passing the applicable FAA written tests on their first attempt during any period of 24 calendar months is at least the percentage figured as follows:

(a) For a school graduating fewer than 51 students during that period—the national passing norm minus the number 20.

(b) For a school graduating at least 51, but fewer than 201, students during that period--- the national passing norm minus the number 15.

(c) For a school graduating more than 200 students during that period---the national passing norm minus the number 10.

As used in this section, “national passing norm” is the number representing the percentage of all graduates (of a curriculum for a particular rating) of all certificated aviation maintenance technician schools who apply for a mechanic certificated or additional rating within 60 days after they are graduated and pass the applicable FAA written tests on their first attempt during the period of 24 calendar months described in this section.

147.39 Display of certificate.

Each holder of an aviation maintenance technician school certificate and ratings shall display them at a place in the school that is normally accessible to the public and is not obscured. The certificate must be available for inspection by the administrator.

147.41 Change of location.

The holder of an aviation maintenance technician school certificate may not make any change in the school’s location unless the change is approved in advance. If the holder desires to change the location he shall notify the administrator, in writing, at least 30 days before the date the change is contemplated. If he changes its location without approval, the certificate is revoked.

147.43 Inspection.

The administrator may, at any time, inspect an aviation maintenance technician school to determine its compliance with this part. Such an inspection is normally made once each six months to determine if the school continues to meet the requirements under which it was originally certificated. After such an inspection is made, the school is notified, in writing, of any deficiencies found during the inspection. Other informal inspections may be made from time to time.

147.45 Advertising.

(a) A certificated aviation maintenance technician school may not make any statement relating to itself that is false or is designed to mislead any person considering enrollment therein.

(b) Whenever an aviation maintenance technician school indicates in advertising that it is a certificated school, it shall clearly distinguish between its approved courses and those that are not approved.

7.17 APPENDIX C
Survey Instrument

Aviation Technical Training & Consulting is under contract to the Federal Aviation Administration to study the certification standards and procedures for AMT training programs. To assist us in this study, please complete the following questions.

Thank you!

1. What is your type of institution (check one)
r Four-year University/College r Community/Technical College
r Proprietary/Private r Vocational/Technical High School

2. How many licensed A&P students did you graduate in 1996-97?________________________

3. List the approximate percentage of graduates who accepted employment in the categories listed below (total should equal 100)
Airlines________ Regional/Commuter________ Corporate Aviation________
General Aviation________ Military________ Repair Stations________
Manufacturers________ Other Aviation________
Non-Aviation________

4. Do you believe the current system of FAA certification and surveillance adequately and fairly assesses the content and quality of your program?
r Yes r No

5. Do you believe the current system of certification and surveillance provides flexibility for curriculum improvement and innovation?
r Yes r No

6. Do you believe your curriculum is currently meeting industry standards?
r Yes r No

7. Do you believe your FAA-PMI has a thorough understanding of the FAR 147 certification and surveillance procedures?
r Yes r No

8. Have you had a consistent interpretation of certification and surveillance guidelines from your FAA inspectors?
r Yes r No

9. Should a program advisory committee be required?
r Yes r No

10. Should the present system of National Norms (FAA written tests) be retained?
r Yes r No

11. Should there be a requirement for faculty development programs?
r Yes r No

12. Should there be a standard transcript to facilitate AMT student transferability?
r Yes r No

13. Should there be national standard(s) for entrance into AMT training programs?
r Yes r No

14. Should the FAA sponsor regional workshops on the training standards for the AMT-T certification?
r Yes r No

15. Should there be national standards for the approval of previous aviation training and experience (military and civilian)?
r Yes r No

16. Which would you rather see as the method for insuring AMT training program quality?
r FAA Surveillance (present method)
r Continuous Quality Improvement
Other (please list) ____

17. How many FAA-PMIs have been assigned to your school in the past five years?_________

18. Which of the following areas cause the greatest problem(s) in the operation of your approved FAR 147 program? Please prioritize (1-11).
r Attendance Policies r Curriculum Modifications r Facilities
r Faculty Qualifications r Student Evaluation r Equipment
r Record Keeping r Training Techniques
r Credit for previous training and experience
r FAA Inspector interpretation of FAR 147
r Other (please list) ______________________________________

7.18 ACKNOWLEDGEMENTS

Charles W. White, Aviation Technical Training & Consulting, and Michael J. Kroes, Purdue University, working in cooperation with the Aircraft Maintenance Division of the Flight Standards Service, prepared this report. This activity was conducted under guidance of the Office of Aviation Medicine Human Factors in Aviation Maintenance Research Program.

The authors wish to thank Mr. Vince Jones, President, and Dr. Richard Dumeresq, Executive Director, and the members of the Aviation Technician Education Council for their assistance with

this project.

CHAPTER 8
HUMAN FACTORS ACCIDENT CLASSIFICATION SYSTEM ANALYSIS OF SELECTED NATIONAL TRANSPORTATION SAFETY BOARD MAINTENANCE-RELATED MISHAPS

CDR John K. Schmidt MSC USN, School of Aviation Safety
Naval Postgraduate School , Monterey, CA

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

8.1 EXECUTIVE SUMMARY

To study maintainer error, the Naval Safety Center's Human Factors Accident Classification System (HFACS) was adapted for maintenance-related mishaps (hereafter referred to only as "mishaps"). The HFACS Maintenance Extension (ME) successfully profiled the errors present and the latent supervisory, maintainer, and working conditions that "set the stage" for subsequent unsafe maintainer acts in 63 Naval Aviation Class A mishaps. In order to assess its suitability for studying major commercial airline accidents, a post hoc analysis was conducted on National Transportation Safety Board (NTSB) reports. Two judges separately coded 15 NTSB Mishaps; a Cohen's kappa of .85 was achieved, indicating an "excellent" level of agreement. Generally, HFACS-ME was able to profile maintainer errors and the factors that contribute to them. Major factors observed include inadequate supervision, failed communications, skill-based errors, and procedural violations.

8.2 INTRODUCTION

Marx[7] in a comprehensive review of maintenance error investigation and analysis systems, states that human error is "under-served" by traditional event investigation methods. He contends that they effectively end with the identification of a human error without an effort to determine why it occurred. Many have previously observed this same problem and attributed it to several factors: 1) reporting criteria, 2) investigator biases, 3) report scope, depth, and quality, 4) reporting system design, and 5) database construction[2,3,4,5,6,7]. Marx[7] reflects that many argue that through a human factors oriented investigation and reporting process "industry can now begin to understand why people make certain mistakes."

Harle[8] posits that "accident prevention is critically linked to the adequacy of the investigation of human factors." However, such systems can be plagued by the same issues as traditional systems if not properly designed, implemented, and supported. Zotov[9], in reflecting on the standard International Civil Aviation Organization (ICAO) reports involving human factors, states they "frequently generated more heat than light." Further, Bruggink[10] finds the reactive use of human factors accident data fails to "exploit the preventive potential of the human element that safeguards the system."

Even though there is a general agreement throughout the aviation industry that human factors based investigation methods are better, they are not being widely used. Marx[7] cited that of 92 carriers trained to use the Maintenance Error Decision Aid (MEDA), only six were in the United States. He notes that this was in spite of the fact that 15 percent of air carrier mishaps are attributed to maintenance error at an annual cost of over a billion dollars. Some of the reasons cited were their tendency to place blame, not transcend the proximate causes, emphasize static who, what, and when variables and not dig for underlying causes.

A conceptual framework of human error that had gained fairly wide acceptance across the government, military, and commercial sector is that established by Reason's model11,12. It showed unsafe individual acts were not the only accident generating agent, and that organization processes and task/environment conditions "set the stage" for their occurrence (see Figure 8.1). Marx7 lamented that despite this acceptance, the model does not provide for the identification precursors to accidents.

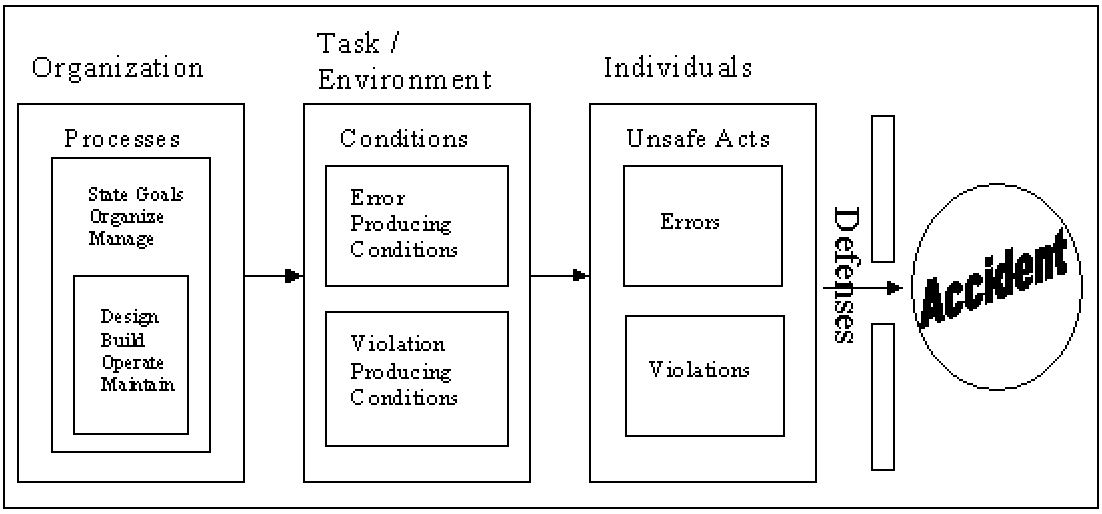

Figure 8.1 Reason's Model

8.3 HUMAN FACTORS ACCIDENT CLASSIFICATION SYSTEM - MAINTENANCE EXTENSION

The Human Factors Accident Classification System (HFACS) was developed by the Naval Safety Center to analyze human errors contributing to Naval Aviation mishaps. It incorporates features of Heinrich's "Domino Theory"13 and Edward's "SHEL Model"14 as well as Reason's model to fully depict factors that are precursors to accidents. Latent conditions and active failures are partitioned into one of three categories (see Figure 8.2). These categories enable an analyst to identify failures at three levels historically related to accidents: supervisory condition, operator condition, and operator act. These classifications can then be used to target appropriate intervention strategies.

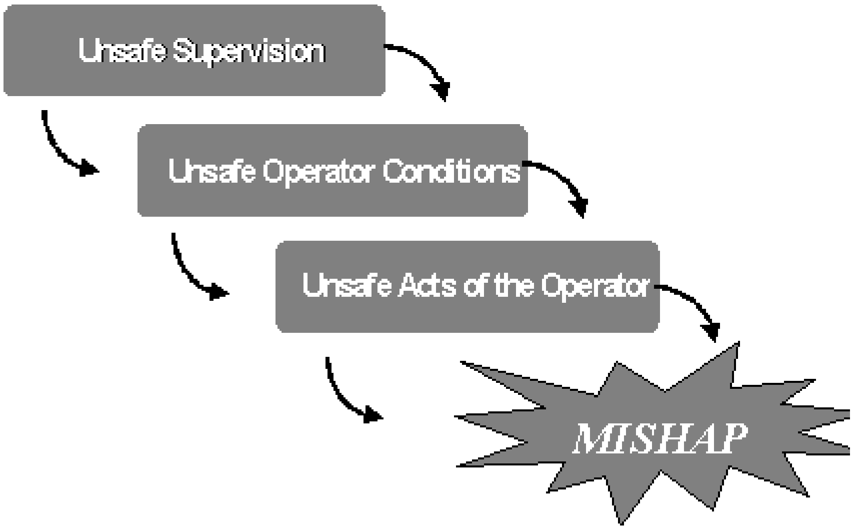

Figure 8.2 HFACS Component Levels

The original HFACS framework was adapted to classify human errors and other factors that contribute to Mishaps. The HFACS addition, termed "Maintenance Extension" (ME), consists of four error categories: Supervisory Conditions (latent), Maintainer Conditions (latent), Working Conditions (latent), and Maintainer Acts (active). The three maintenance error orders reflect a shift from a molar to a micro perspective (see Table 8.1).

Table 8.1 Error Categories of HFACS Framework

First Order	Second Order	Third Order
Supervisory Conditions	Unforeseen	Hazardous Operations Inadequate Document
	Squadron	*Inadequate Design* *Inadequate Supervision* *Inappropriate Operations* *Uncorrected Problem* *Supervisory. Violation*
Maintainer Conditions	Medical	Mental State Physical State Physical/Mental limitation
	Coordination	*Communication* *Assertiveness* *Adapt/Flexibility*
	Readiness	**Prep/Training** **Qualification/Certification** **Violation**

Working Conditions	Environment Equipment **Workspace**	Lighting/Light Exposure/Weather Environmental Hazards *Damaged* *Unavailable* *Dated/Uncertified* **Confining** **Obstructed** **Inaccessible**
Maintainer Acts	Error Violation	Attention Memory Rule/Knowledge Skill *Routine* *Infraction* *Exceptional*

The following paragraphs provide a brief illustration of the HFACS Maintenance Extension taxonomy levels:

Latent Supervisory Conditions that can contribute to an active failure includes both "*Unforeseen*" and "*Squadron.*"

Examples of *unforeseen supervisory conditions* include:

- An engine that falls off of a stand during a change-out evolution due to an unforeseen hazard of a high seas state (Hazardous Operation)
- A manual omits a step in a maintenance procedure, such as leaving out an o-ring that causes a fuel leak (Inadequate Documentation)
- The poor layout of system components that do not permit direct observation of maintenance being performed (Inadequate Design)

Examples of *squadron supervisory conditions* include:

- A supervisor who does not ensure that maintenance personnel are wearing required personal protective gear (Inadequate Supervision)
- A supervisor who directs a maintainer to perform a task without considering risks, such as driving a truck through a hangar (Inappropriate Operations)
- A supervisor who neglects to correct maintainers who routinely bend the rules when they perform a common task (Uncorrected Problem)

- A supervisor who willfully orders a maintainer to wash an aircraft without proper safety gear (Supervisory Violation)

Latent Maintainer Conditions that can contribute to an active failure include "*medical*," "*crew coordination*," and "*readiness*."

Examples of *maintainer medical conditions* include:

- A maintainer who has a marital problem and cannot focus on a maintenance action (Mental State)

- A maintainer who worked for 20 hours straight and suffers from fatigue (Physical State)

- A maintainer who is short can not visually inspect aircraft before it is launched (Physical Limitation).

Examples of *maintainer crew coordination conditions* include:

- A maintainer who leads a taxiing aircraft into another due to improper hand signals (Communication)

- A maintainer who performs a task, not in accordance with standard procedures, because the maintainer was overly submissive to a superior (Assertiveness)

- A maintainer who downplays a downing discrepancy to meet the flight schedule (Adaptability)

Examples of *maintainer readiness conditions* include:

- A maintainer who is working on an aircraft skipped the requisite OJT evolution (Training)

- A maintainer who engages in a procedure that they have not been qualified to perform (Certification)

- A maintainer who is intoxicated on the job (Violation)

Latent Working Conditions that can contribute to an active failure include "*environmental*," "*equipment*," and "*workspace*."

Examples of *environmental working conditions* include:

- A maintainer who is working at night on the flightline does not see a tool he left behind (Lighting/Light)

- A maintainer who is securing an aircraft in a driving rain fails to properly attach the chains (Weather)

- A maintainer who is working on a pitching deck falls from the aircraft (Environmental Hazard)

Examples of *equipment working conditions* include:

- A maintainer who is using a defective test set does not precheck it before troubleshooting (Damaged)

- A maintainer who starts working on landing gear without a jack because all in use (Unavailable)

- A maintainer who uses an old manual because a CD-ROM reader is not available (Dated)

Examples of *workspace working conditions* include:

- A maintainer who is working in a hangar bay cannot properly position the maintenance stand (Confining)
- A maintainer who is spotting an aircraft with his view obscured by catapult steam (Obstructed)
- A maintainer who is unable to perform a corrosion inspection that is beyond his reach (Inaccessible)

Maintainer Acts are "*active failures*," which directly or indirectly cause mishaps, or lead to **Latent Maintenance Condition**; this category includes errors and violations.

Examples of *errors in maintainer acts* include:

- A maintainer who misses a hand signal and backs a forklift into an aircraft (Attention)
- A maintainer who is very familiar with a procedure may reverse steps in a sequence (Memory)
- A maintainer who inflates an aircraft tire to a pressure required by a different aircraft (Rule)
- A maintainer who roughly handles a delicate engine valve causing damage (Skill)

Examples of *violations in maintainer acts* include:

- A maintainer who engages in practices, condoned by management, that bend the rules (Routine)
- A maintainer who strays from accepted procedures to save time, bending a rule (Infraction)
- A maintainer who willfully breaks standing rules disregarding the consequences (Exceptional)

Following the HFACS-ME, **Supervisory**, **Maintainer**, and **Working Conditions** are latent factors that can impact a maintainer's performance and can contribute to an active failure, an **Unsafe Maintainer Act**. An **Unsafe Maintainer Act** may lead directly to a mishap or injury. For example, a maintainer runs a forklift into the side of an aircraft and damages it. The **Unsafe Maintainer Act** could also become a latent **Maintenance Condition**, which the aircrew would have to deal with on take-off, in-flight, or on landing. For example, an improperly rigged landing gear that collapses on touchdown or an over-torqued hydraulics line that fails in flight causing a fire. It is important to note that **Supervisory Conditions** related to design for maintainability, prescribed maintenance procedures, and standard maintenance operations could be inadequate and lead directly to a **Maintenance Condition** (see Figure 8.3).

Figure 8.3 HFACS Maintenance Extension Model

The following summary15 is an example of the use of HFACS-ME in analyzing a existing data set. During FY 90-97 there was a total of 63 Class A mishaps, of which 61 were Flight, 0 were Flight Related, and 2 were Aircraft Ground. Two Navy Maintenance Officers and two Navy Chiefs used the HFACS Maintenance Extension to classify the human factors causes reported in these mishaps. They uncovered the following human error profile for Naval Maintenance Related Mishaps. See Figure 8.4 for all graphical representation of the summary data.

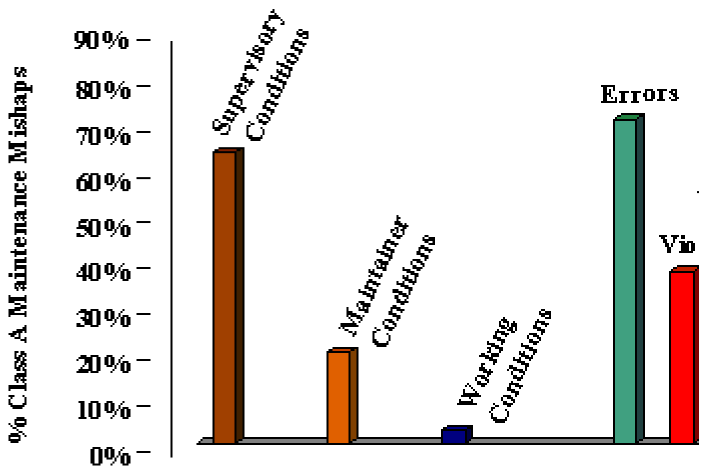

Figure 8.4 HFACS Profile of Class A Mishaps.

Supervisory Conditions - 67% of all Naval Aviation Class A Mishaps reported Squadron Supervisory Conditions, whereas 21% had Unforeseen Supervisory Conditions (not shown).

Maintainer Conditions - 21% of all Naval Class A Mishaps reported Medical, CRM, or Readiness Maintainer Conditions. *Note: Maintainer Conditions were under reported, more are likely present and have an effect.*

Working Conditions - 3% of all Naval Class A Mishaps reported Environment, Equipment, or Workspace Working Conditions. *Note: Workspace Conditions were under reported, more are likely present and have an effect.*

Maintainer Acts - 75% of all Naval Aviation Class A Mishaps reported Maintainer Errors, whereas 40% had Maintainer Violations.

Clearly, latent conditions in the form of Supervisory, Maintainer, and Workspace factors are present that can impact maintainers in the performance of their jobs. However, many Maintainer and Workspace Conditions are not reported due to the reporting system in place, perceptions of accident causation, or culture/climate issues. Specifically, inadequate supervision of maintenance evolutions, not ensuring personnel are trained and/or qualified, not enforcing rules, and poor communication characterize the majority of latent Supervisory Conditions. Poor passdown, coordination, and communication; non-use or lack of publications, policies, and procedures; and fatigue comprise most latent maintainer conditions. Finally, most Maintainer Errors reflect a lack of training, experience, and skill, whereas Maintainer Violations consist of routine non-compliance with standard procedures and practices, infractions, and bending the rules in order to meet mission requirements and the flight schedule.

The HFACS-ME was effective in capturing the nature of and relationships among latent conditions and active failures present in Class A mishaps. The insights gained provide a solid perspective for the development of potential intervention strategies. The major mishaps analyzed were primarily Flight Mishaps (FMs,) meaning that many imposed in-flight Maintenance Conditions on aircrew.

8.5 OBJECTIVE

The Federal Aviation Administration (FAA) has a sustained interest in the application of human error models and taxonomies to Mishaps. This interest is maintained in order to facilitate the identification of human factors problem areas as well as to provide a basis for the development of tailored intervention strategies. Given a stated desire to uncover all levels of human error that contribute to a mishap and to proactively use such an analysis in prioritizing and focusing safety efforts, the FAA Office of Aviation Medicine requested that the HFACS-ME be applied post hoc to several commercial airline mishaps. In addition, the HFACS-ME was characterized according to the criteria laid outlined in the Marx report7.

8.5.1 Methods

Database. The NTSB/FAA Maintenance Accident Report Infobase constructed by Galaxy Scientific Corporation for the FAA Office of Aviation Medicine contains a total of 24 NTSB accident investigation reports. This database provided the source of information used for this assessment. The reports examined all had maintenance as a contributing causal factor. The reports were provided by the Honorable John Goglia, NTSB Member. Infobase offers full-text search and hyperlinking capabilities which are invaluable tools for researchers and users to review past mishaps.

Judges. The author and a Navy Maintenance Officer, both experienced in maintenance operations and well versed in the HFACS-ME axonomy, reviewed the Infobase reports and selected 15 (63%) as clearly having maintenance as a contributing causal factor (see Table 8.2). Those excluded involved an inflight lavatory fire, a lightning strike followed by a fuel cell explosion, a fatality from malfunctioning inflight service equipment, incorrect take-off/approach procedures, and catastrophic engine failures. The mishaps were coded independently by the two judges and Cohen's kappa was calculated as a measure of agreement and reliability. A kappa of .85 was achieved, indicating an "excellent" level of agreement between the two raters.

Table 8.2 NTSB Accident Reports Selected for Analysis

Date	Aircraft	Company
08/21/95	EMB-120RT	Atlantic SE Airlines
01/07/96	DC-9-32	ValuJet Airlines
06/08/95	DC-9-32	ValuJet Airlines
12/14/94	Learjet 35A	Phoenix Air Group
03/01/94	B747-251B	Northwest Airlines
09/11/91	EMB-20RT	Britt Airways/Cont.Exp
07/19/89	DC-10-10	United Airlines
03/18/89	DC-9-33F	Evergreen Int'l Airlines
02/24/89	B747-122	United Airlines
04/28/88	B737-200	Aloha Airlines
05/05/83	L1011	Eastern Airlines
09/22/81	L1011-385	Eastern Airlines
09/22/81	DC-10-30CF	Air Florida Airlines
05/25/79	DC10-01	American Airlines
02/08/76	DC-6/YC-112A	Mercer Airlines

Procedure. Each mishap case was independently reviewed and the HFACS-ME codes for each case were entered into a spreadsheet for subsequent tabulation. Each causal factor was assigned only one HFACS-ME code, and codes were only assigned to issues clearly identified as having had contributed to the mishap. Codes that were disputed were discussed and resolved on the spot or after conferring with a third party.

Analysis. Each HFACS-ME category level was totaled and frequencies were either entered into a chart for subsequent inspection.

8.5.2 Results

The percentage involvement of each second level HFACS-ME factor for the 15 mishaps provided in the NTSB/FAA database is presented below (see Figure 8.5). There were a total of 36 maintenance causal factors taken from the 15 Mishaps, averaging 2.4 factors per case.

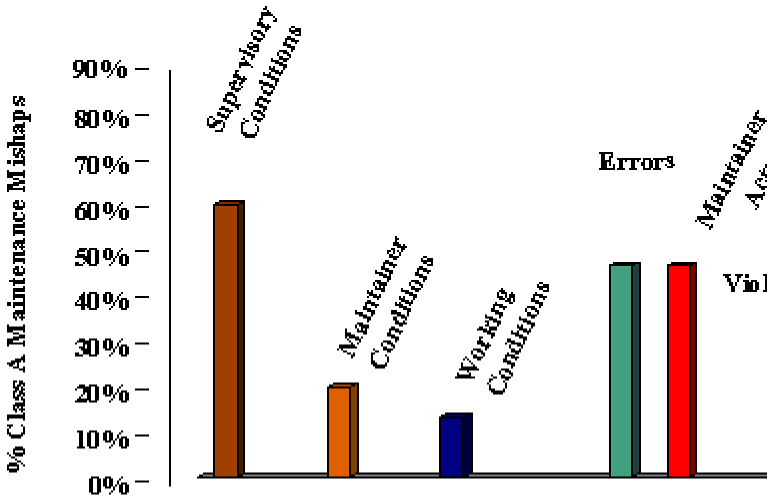

Figure 8.5 HFACS Profile of 15 NTSB/FAA Mishaps

Supervisory Conditions – 60.0% of the 15 NTSB/FAA mishaps reported Company Supervisory Conditions, whereas 26.7% had Unforeseen Supervisory Conditions (not shown). The majority of supervisory issues involved inadequate procedures, supervision, and training.

Maintainer Conditions – 20.0% of the 15 NTSB/FAA mishaps reported Crew Coordination. *Note: Maintainer Conditions were under reported, more are likely present and have an effect.* Pass down of information within work groups and from the company to the employees was listed.

Working Conditions – 13.3% of the 15 NTSB/FAA mishaps reported Environment and Workspace Conditions. *Note: Workspace Conditions were under reported, more are likely present and have an effect.* Lighting and confined workspace were mentioned as factors.

Maintainer Acts – 46.7% of the 15 NTSB/FAA mishaps reported Maintainer Errors, whereas 46.7% had Violations. Most errors entailed omissions or incomplete procedures, whereas violations involved not following procedures.

8.6 CONCLUSIONS

The HFACS-ME was effective in capturing the nature of, and relationships among, latent conditions and active failures present in NTSB/FAA mishaps. The insights gained provide a solid perspective for the development of potential intervention strategies. These major mishaps primarily occurred in-flight, meaning they imposed Unsafe Maintenance Conditions on the aircrew. Observed elements of inadequate supervision, procedures, and training, communication breakdowns on procedural changes, inspection and omission errors, and procedural violations make up the bulk of the observed human error causal factors. Based upon these findings, the primary errors sources can be prioritized and then targeted for intervention.

Since most major mishaps involve only flight operations, it is essential to evaluate the more minor ones that occur on the ramp and in the hangar. Such mishaps involve activities that can lead directly to damage to the aircraft or injury to the maintainer. Consequently, the present profile for major mishaps cannot be generalized to all mishaps of lesser severity. It is essential to apply HFACS-ME to minor incidents to get at the whole maintenance-related mishaps picture. Further, it can be contended that interventions developed for major mishaps involving maintenance activities, such as engine repair, are not likely to be appropriate for ones of lesser severity that involve other activities such as cargo loading or aircraft towing.

8.6.1 System Comparison Criteria

Using the criteria provided in the Marx report7 on maintenance error nvestigation and analysis systems, the HFACS-ME is classified as follows:

Name:	Human Factors Accident Classification System-Maintenance Extension (HFACS-ME)
Characterization:	Error Investigation and Analysis Methodology
Owner:	Dept. of the Navy; United States Government
Scope of Investigation:	Major/Minor Events and Potential Discrepancies
Investigative Approach:	Assigned Investigators
Structured Data Analysis:	Single Event; Graphical, Aggregate Profile,Trend, & Comparative Analysis; used w/ Categorical Data Analysis, Logistical Regression, & Stochastic Modeling
Structured Prevention/Strategy Development:	Operational Risk Management
Structured Monitoring and Feedback:	Event, Cost, & Risk Trending

The information that is provided depicts both the current, as well as projected attributes of HFACS-ME. To date, HFACS has been applied to study major and minor Mishaps, maintenance related incidents and injuries, trend and cost analysis, models of future event frequencies, and statistically significant human error patterns.

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CHAPTER 9
TECHNOLOGY BASED SOLUTIONS FOR PROCESS MANAGEMENT IN AVIATION MAINTENANCE

Jeff Millians
Galaxy Scientific Corporation

Anand Gramopadhye
Clemson University

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

9.1 EXECUTIVE SUMMARY

A prototype electronic data management / process data management (EDM/PDM) software system was created using off-the-shelf software. The participating industry partner was the Lockheed Martin Aircraft Center in Greenville, South Carolina. The system was designed to replace the current process of service order work instruction deck creation. The current non-EDM/PDM process was assessed and documented in detail by the researchers via close observation and extensive discussion. Once the process was documented, checked, and approved, an electronic version of the process was created within a software system. All paper-based elements (i.e., forms, references, etc.) were transferred into electronic format either by scanning the originals or by creating a copy with a word processor. Once complete, the prototype was given to the planning personnel to use and assess. The results of the assessment suggest a savings of approximately 32 person-hours (80%) per service order in the planning stage alone. The current process requires an average of 40 person-hours while the prototype electronic process requires an average of six person-hours. A questionnaire completed by the planning personnel suggests that the prototype system is more efficient, less error prone, less time- consuming, and easier to use than the current process. A brief history of EDM/PDM along with a detailed description of the current study follows.

9.2 INTRODUCTION

The aircraft maintenance system is a highly complex one consisting of several human and machine components. (FAA, 1993, 1995). Currently, the large portion of the aircraft maintenance workflow is controlled through such written documentation as workcard instructions, manuals, airworthiness directives, and non-routine work instructions and has been reported to be redundant and inefficient. In light of this situation, it is critical that we identify interventions to make the system more effective, efficient, and reliable. Moreover, increased global competition in the aviation industry with increased focus on improving safety and efficiency has forced many companies to focus on their maintenance-related processes. Reduced funding, shorter schedules, and increased competition have created a need for achieving maximum efficiency without compromising safety. At every stage of the maintenance cycle, data is generated, but only when the required data arrives at the right place at the right time does it improve efficiency. With the advent of "enterprise-wide" electronic data management (EDM) systems, every industry now has the opportunity to effectively control its information, eliminate the proliferation of redundant data, and accommodate shorter life cycles. These opportunities can be realized while simultaneously raising quality and reducing costs.

PDM, a derivative of Electronic Data Management and electronic workflow, was specifically designed to address the demands and requirements of process-driven industries such as manufacturing and maintenance. Thus, PDM is intended to reduce error rates, improve regulatory compliance, accelerate turnaround times/product cycles, and lower costs. The literature reports several successful case studies in the implementation of PDM to improve workflow in non-aviation environments (Atkinson & Glasscock, 1990; Bryan, 1997; Bowman, 1996). Despite the successful use of PDM in non-aviation environments, its use in aviation, and specifically for maintenance, is lacking.

In response to this need, the Federal Aviation Administration (FAA) Aviation Maintenance and Inspection Human Factors Research Program looked at the applicability of PDM/EDM in aircraft maintenance. As part of this research, Galaxy Scientific Corporation assessed the extent to which off-the-shelf EDM/PDM software could be applied to aircraft maintenance tasks. The tasks include the following: controlling updates to manuals, regulations, and other written documentation; managing information transfer; improving completeness and accuracy of information entered on forms; making reference information more readily and rapidly available; and expediting lookups, cross-references, etc. Secondly, the research was conducted in cooperation with Lockheed Martin Aircraft Center to demonstrate the applicability of EDM/PDM in the aviation maintenance environment. The research called for an in-depth task analysis of the entire maintenance process, from service order scheduling to final release.

Measures included such requirements as:

- Time, cost, infrastructure, and services,
- Worker acceptance of process automation,
- The readiness of the environment for technology-based solutions including whether the documents were in electronic format, the workflow sufficiently defined, and computer equipment in place or in use,
- The overall viability of implementing PDM,
- The probable results of implementing PDM in an aviation maintenance environment.

In summary, the specific objectives of the research were as follows.

- To review the applicability of off-the-shelf PDM software in the aircraft maintenance environment.
- To develop a prototype PDM system demonstrating the possible improvements in effectiveness and efficiency for a representative aircraft maintenance process.

A brief review of the literature dealing with the increased application of PDM/EDM, in various other industries and environments, follows.

9.3 PDM BACKGROUND

The history of PDM itself can be traced back several years. PDM has evolved over two distinct phases: EDM (Electronic Data Management) and PDM (Process Data Management). EDM products satisfied relatively simple requirements by enabling secure management of an organization's computer automated drawing (CAD) data on a single system. PDM extended the data management capabilities of EDM systems to cover data from the manufacturing stage as well as the design stages of a product's life cycle. Thus, the term PDM, which has come to describe the enhanced capabilities of these systems, supports the entire product life cycle and the management of a wide variety of data.

In the early 1980's, large corporations found their progress seriously hampered by paper-based systems. Hence, they tried to develop solutions internally, as no commercial systems were available. In the early 1990's, several software companies, realizing the need and associated business opportunity for such a product**,** introduced the first generation commercial off-the-shelf PDM systems. The basis of these PDM systems is the database engine on which are stored records of parts and related files. PDM involves collecting, managing, and disseminating all data about a product's whole life cycle from design to decommissioning. Thus, PDM technology is used to manage product-related information and processes. The challenge for PDM is to maximize the time-to-market benefits of concurrent engineering while maintaining control of data and distributing it automatically to the people who need it when they need it. The way PDM systems cope with this challenge is by holding master data only once in a secure "vault" where its integrity can be assured and all changes to it monitored, controlled and recorded (see Figure 9.1). Duplicate reference copies of the master data, on the other hand, can be distributed freely to users in various departments for design, analysis, and approval. The new data is then released back into the vault. When a "change**"** is made to data, a modified copy of the data is signed, dated, and stored in the vault alongside the old data, which remains in its original form as permanent record. This is the simple principle behind today's advanced PDM.

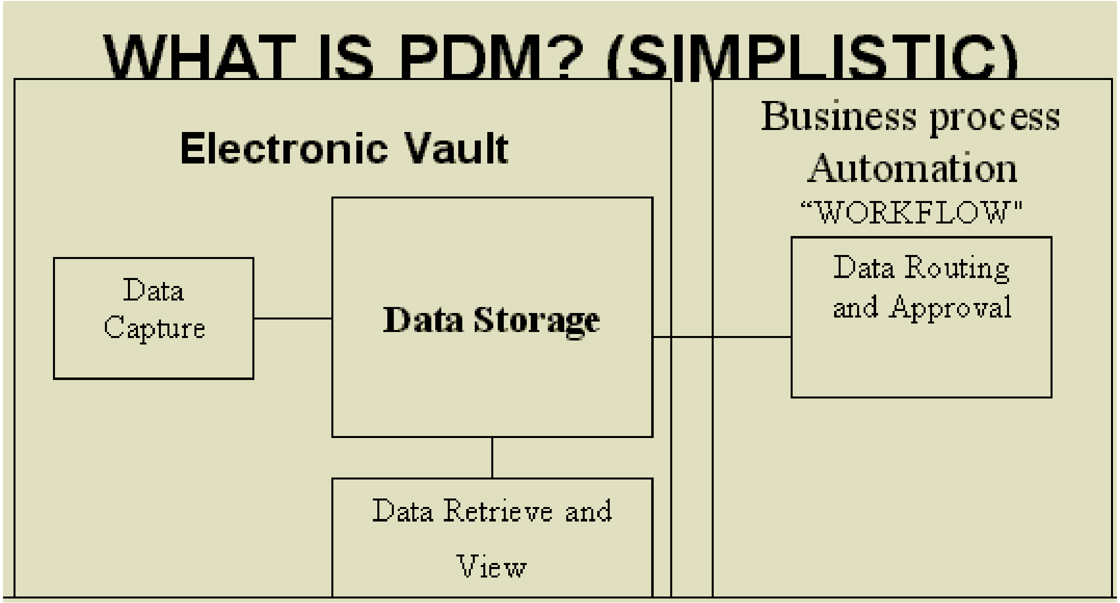

Figure 9.1 A Simplistic View of a PDM

Literature on PDM talks about several successful implementations of PDM in industry. Harris (1996) refers to published case studies of PDM implementations from large companies producing complex products, for example: Boeing (Atkinson, 1990), Honeywell (Gerdeen & Hansen, 1990), VSEL (Haddleton, 1993), DTI booklet case studies (Rockwell Graphics and Thorne Emi Elextronix Limited-Sensors Group)**,** DTI seminar cases (Rover, Westinghouse Signals Group, Penhallow, 1994), and the Kalthoff Conference cases (GEC-Marconi Defence Systems, W. Lucy and Company Limited, Fokker Space and Systems B.V., GEC Alsthom Metro-Cammell Simited, SAAB Military Aircraft and Short Brothers) (Conference workbook, 1995). The vast majority of respondents to the CIM data PDM Implementation Survey had over 1000 employees and turnovers in excess of US$250 million; however, no case studies have been found from smaller companies producing less complex products (Dorfman, McKrell, Miller, Philpotts, and Romzick, 1994).

A recent study by MacDonald (1996) demonstrated the benefits that early adapters of PDM are now achieving. PDM reduced the time needed to develop new products and process engineering changes, including the costs of administering these changes. The implementation of PDM resulted in a reduction of up to 20 percent in engineering and manufacturing labor costs resulting from the reduction of non-value added activities associated with information handling.

A similar success in the implementation of PDM has been reported by MacDonald wherein a customized off-the-shelf software was used to implement a PDM system that concentrated first on the MRP II and accounts business system. The companies focused on a user-centered approach by ensuring that the implementation team was representative of all potential users of the new systems, including interfacing organizations. Currently, the PDM system helps to integrate more than 350,000 engineering data records loaded from the existing database. Tinham (1998) describes the implementation of PDM at Honeywell. The company obtained incremental benefits and a good return on investment from its phased PDM implementation. Honeywell succeeded because it addressed the technical, the organizational, and the people challenges of PDM by approaching it in a structured way, implementing PDM one phase at a time and keeping the scope of each under tight control. Siegel (1995) reports how the PDM implementation team at the Atlanta-based Retail Products and Systems Division of AT&T Global Information Solutions overcame all the hurdles to deliver a world-class PDM system in less than a year. PDM supported the development releases (including drawings and schematics), engineering changes, stop orders, engineering product structure, configuration management and bill of materials. PDM brought the paper-driven process into the electronic age and consolidated the Bill of Materials, eliminating most of the paper files and signing off documents via e-mail. It handled the product structure from part to assembly, to feature and beyond.

Foley (1995) describes a PDM system at Warner Electric Rotary Motion Division of Dana Corp, a Fortune 100 company. This company began the implementation process with document management (drawing and data). In the second phase, it implemented workflow within the engineering department and in the third phase completed the bill of materials management. PDM helped to speed up the product development, manufacturing process and time to market by making data and drawings more accessible to the people who needed them.

Companies have realized the numerous benefits of implementing PDM. First, companies save money because of improved productivity and reduced waste. All versions of all data are located in the software system. This data storage capability aids in paper trail audits as well as version control. Second, the data storage improves ability to find correct data quickly. Most of the software systems include the capability to not only search for documents, but also to search within documents. This capability is most advantageous in time restricted projects. Third, the EDM/PDM software system improves process and workflow. Because the process follows a predetermined workflow, it will be near impossible to skip or forget procedural steps within the workflow. This is because, fourth, software improves integrity, tractability, and auditability of processes and data. All procedural steps are tracked and all changes are noted. The software serves as a governor of the process. And last, EDM/PDM software systems improve change management and configuration management processes. The time taken for engineering changes can be reduced by 60 percent. As stated before, all changes are noted and stored. If a need arises for a previous version of a document, that version can be located and collected.

The major steps in implementing PDM systems are: (1) Identifying and prioritizing the company's goals, (2) Understanding business processes and user needs, (3) Understanding current document management, (4) Managing business change, (5) Developing the system (6) Testing the system, and (7) Conducting a cost-benefit analysis.

The key issue in developing a PDM strategy involves creating and manipulating the product data by looking at all stages of the life cycle including inputs and outputs, data travel, data use and technology. Key factors for successfully implementing PDM are an empowered staff and the willingness to engage all disciplines in the design process right from the start. In addition, the use or existence of function and product-oriented teams, co-location for all design disciplines, state-of-the-art computer tools, appropriate and timely staff training, concurrent development and review of all product data, and unwavering management support will lead to success.

Despite several success stories, the use of PDM still lacks support within organizations. The main barriers observed in industry for implementing PDM are the users of the system itself and the culture. Users act as barriers mainly because of their lack of awareness. The culture comes into picture because implementing PDM requires substantial changes in organization. As Ballinger

(1996) stated about PDM implementations, “the technology was not the problem; the big issue was culture.” PDM does not exit in isolation; it feeds off of and in turn feeds other systems. Literature tells us the reasons why the implementation could fail. Reasons include:

1. Management won’t fund it,
2. A better product is coming out next year,
3. Our CAD package does enough PDM for us already,
4. Management doesn’t understand the benefits,
5. We’re different! No COTS solution will work for us,
6. We’re waiting for our IS department to finish the long-range system plan,
7. Our corporate re-engineering project needs to finish first, before we start a PDM project,
8. We’ll let other companies fix the bugs and make the mistakes first, before we jump in,
9. We already brought one but had trouble implementing it and they (WHO) fired the leader and promoted the uninvolved,
10. We’re spending all of our time and money implementing SAP.

9.4 PDM IN THE AIRCRAFT MAINTENANCE ENVIRONMENT

9.4.1 Introduction

The prototype software used a customized version of an “off-the-shelf” document management software program called NovaManage. This software, which was developed by NovaSoft Systems, Inc., was chosen because of its highly customizable characteristics. The researchers customized NovaManage for the specific needs of the planning department of Lockheed Martin Aircraft Center.

The PDM/EDM software was developed in a modular fashion with different levels of access and authorizations. The access levels determine the degree of authorization, which, in turn, establish the degree of control available to the different users having access to the system. The development of the PDM software followed the classic iterative development methodology. This software capitalizes on principles of graphical user interface design and human-centered factors design. The software was designed as a “proof of concept” approach to demonstrate the use of an electronic documentation tool in the aircraft maintenance environment. As such, the software is only a prototype for studying the effects of electronic documentation for a representative process in the aircraft maintenance industry (the process is described in greater detail later). Another purpose is to demonstrate the effective use of off-the-shelf software for the implementation of EDM/PDM functionality into an existing task flow architecture.

9.4.2 Description of the Representative Process -- A Test Bed for PDM

A representative process from the aircraft maintenance environment was selected to demonstrate the use of EDM. The specific process selected was the one of “creation of work instruction cards” by the Planning Department for use on the hangar floor. The researchers created the software prototype for the Planning Department to automate the tasks associated with work deck creation. Appendix A describes the terms used in the task description.

9.4.3 Workcard Creation: Task Description

Simply stated, a workcard instruction identifies the series of steps that need to be taken by the AMT and/or inspector so that work adheres to mandated procedures. Before the instructions can be made available to the hangar floor, they have to be put together and passed through a series of approvals. Only then can these instructions become an official source of work instruction. The existing process for workcard creation is essentially a manual one that is generated and accomplished by the Planning

Department.

At Lockheed, the representative aircraft repair facility, a set of workcard instructions has to be put together for each service order for each aircraft. The planner puts the orders together. Each order (scheduled maintenance appointment) consists of from one to more than fifty work instructions, each of which includes references to the aircraft maintenance manual, graphics, parts lists, and check-out cards. Following its creation, the service order is routed for approval through the appropriate authorities – the customer and the quality assurance personnel. Appendix B shows a flow chart of the decision-making approval process. At each step of the approval process, the work card instructions are reviewed, approved, and forwarded to the next stage for processing. Discrepancies and corrections are resolved through an iterative process. Once the entire deck is approved, it comes back to the planner where it resides, ready for distribution to the hangar floor. Creation of a complete work card deck (all of the work instructions for a given service order) currently requires up to forty person-hours.

9.4.4 Step-by Step Description of the Work Instruction Creation Process

9.4.4.1 Manual System

The current operation sequence begins when a customer schedules an aircraft maintenance service with the repair facility (see Appendix B for a list of steps and a flow chart of activities). The administration notifies the Planning Department of the pending service order, and the Planning Department prepares the required workcard deck.

Initially, the appropriate workcards contained within a single deck are located. Some cards are in an electronic format (Microsoft Word) whereas others are available on hard copy in filing cabinets. In either case, a copy of the work card is created using a standard copying machine. If the work card includes references or graphics, extra blank work card pages are created. At this point, the reference pages are copied. The copies are then cut and glued onto the blank work card page. Following this step, the page is copied, and the copy is added to the work card. This process is repeated for every reference page and every graphic. Upon completion of the workcard deck, a service order number label is created by notifying the administration, and a corresponding bar code label is created and printed. This label is manually affixed to the workcard.

Once the entire deck is completed, it is sent to quality assurance (QA) for approval. The appropriate QA personnel review and verify the content of each work card and approve it by manually stamping it. Following approval, the deck is sent to the customer for approval. Each approval step requires physically carrying the deck to the appropriate office for approval.

9.4.4.2 PDM System

With the proposed software, all steps can be accomplished at the computer.

For research purposes, two major assumption were made. First, the creators of the software prototype assumed that all relevant documents, work cards, manuals, graphics, etc. are available in an electronic format or contained within the computer system so that they can be easily accessed using a word processor, spreadsheet, or other document creation software. While a large portion of the paper documentation can be transferred to an electronic version with minimal time and effort, some, such as the reference manuals, will require large amounts of time and money. Also, copyright laws may prevent any transfer of the reference manuals.

The second assumption deals with intranet or client / server connectivity. Because the software includes workflow processes requiring the participation of many offices, to use the prototype software properly and effectively, a network must exist. At the present time, the office in question is not connected to any other office.

The planning process begins with the creation of a service order. Appendix C shows representative screens viewed by the user in creating the work deck. Within the software, a service order is an entity containing all the necessary documents. A window appears along with a list of the folders (directories) containing the necessary documents. The work cards, listed by number and revision, are then "dragged and dropped" into the service order window. All needed reference material and graphics are included with or linked to the work instruction cards. Following this step, the software generates a bar code on each work card. An electronic work flow is chosen by the planner from a list of workflows in the system. The deck is then placed in the workflow, which includes edit, approval, and QA tasks. Once the process is started, the next person listed, in this case QA, is notified via email to enter the system and check the deck online. Upon approval, the person simply presses a "Stamp" button and enters his or her password to allow the deck to proceed to the next step in the workflow. After all parties have approved the deck, it is sent electronically to the hanger floor.

9.4.5 Evaluation of the PDM system

9.4.5.1 Development Methodology

The software was developed using a task analysis and an iterative software development methodology. The salient steps are described below.

9.4.5.1.1 Establishing the Representative Process

The researchers observed and studied the entire maintenance process, from service order scheduling to final release. The planning office begins the process by scheduling a service order. Once the accounting office approves the service order, the planning office then creates the needed forms package (deck) for the hangar floor. Following a series of checks, the deck is delivered to the hangar floor. The maintenance manager then assigns specific tasks (work instruction cards) contained in the deck to specific individuals or groups. Upon completion, each step contained on the work instruction card is checked and approved by quality control personnel and by the customer. While all steps must be inspected and approved by quality control personnel, some steps must be completed and approved before subsequent steps can begin. The total work time spent on each work instruction is recorded for billing purposes by a check-in / check-out, timestamp operation.

A number of the steps reference maintenance manual pages, graphics and drawing, and / or materials and parts lists. The planning office is responsible for incorporating these references into the work deck aside the relevant work instruction card. However, the hangar floor maintenance personnel are responsible for materials and parts ordering and check-off.

Following the overall task analysis of the aircraft maintenance processes, the "work deck generation" process was selected as representative to demonstrate the use of PDM/EDM. Reasons for this decision include: (1) the planning office process requires the participation of only two people, as opposed to 50 to 60 on the hanger floor, (2) the tasks performed by the planning office demonstrate the most salient process inefficiencies, and (3) the work instruction card is the heart of the maintenance and inspection process.

9.4.5.1.2 Conducting the Analysis of the Existing Process

A detailed task analysis of the existing process was conducted by collecting data through observations, interviews, and shadowing techniques. Researchers spent two days observing the planning office personnel in action. After the first day, a detailed outline similar to the outline found in Appendix B was created by the researchers and reviewed by the planning office for final approval. All corrections were made to the outline before the second day of observation.

On the second day, the outline was checked against the ongoing tasks. The analysis revealed that the process for deck creation typically required an average of 40 hours for the Planning Department. Also, the forms were explained in detail. A sample of the forms is found in Appendix G. Following the analysis of the existing manual process, the system developers developed a detailed task analysis outline to identify the critical steps and the approval protocols. Appendix B shows the representative task outline along with a hierarchical functional flow diagram.

9.4.5.2 Developing the Prototype System

The final prototype was developed using the concepts of storyboarding, paper prototyping, and iterative software creation. Employing the basic components of the software, window behavior documents (WBDs) were created using human factors, graphical user interface (GUI) design principles. This method of storyboarding is key to a more user-friendly interface. The WBDs are found in Appendix F. The WBDs were shown to the planning office personnel. The personnel were asked to state their interpretation of buttons and window order without any prior knowledge of the software. This heuristic evaluation of the paper prototype proved very useful in matching the actual design of the software with the perception of the potential users.

9.4.5.2.1 Demonstrating and Testing the System

Following the development of the EDM system, it was demonstrated to the Planning Department at the research partner's facility. Two senior planners used the system, after which they completed a questionnaire evaluating the EDM system. Appendix D includes the survey administered to the users. The participants answered questions relating to usability and usefulness of the system.

9.5 ANALYSIS ON THE USE OF PDM

Following the development of PDM, senior planners analyzed the system. The results of a questionnaire, on the usefulness of the system and the usability of the system, are summarized in Appendix E. The analysis, though limited in sample size, reveals that the system, if converted into a fully usable system, has the potential to make the existing process highly effective and efficient. The average time for work card generation and approval process will be reduced from the existing 40 person-hours to six person-hours. This can be very significant for an airline looking for costs savings or reduction in labor hours. Other major advantages of using such a system are:

1. Improved accuracy and integrity in the process
2. Secured data transfer
3. Electronic approval process
4. Superior record keeping and detailed record n history of updates
5. Different levels of access based on user types
6. Portability
7. Ease in integration with other systems (e.g., person-hours worked on job, tracking job status)

The system also scored high on usability and interface design issues, which is a testament to the methodology employed in the development of the prototype system. The existing system was developed using a task analytic and a user centered methodology employing human factors principles of system and interface design. The average score on usability and interface design issues ranged from a high of 1.5 to a low of 2.5. (1 indicates agree and 5 strongly disagree) (see Appendix E). The high number of favorable responses secured by the system indicated that the system if made available to the users will be used by them and that they were comfortable in using the system. Responses to questions 17, 18, 19 and 20, which compared the new system with the existing manual system, revealed that the planners preferred the new system to the existing system on all the issues. Interestingly, on question 12, which focused on acceptability of the tool across the company, the planners were neutral. This response could be a reflection of the apprehension that exists within today's organizations to accept new and novel solutions to existing problems. The problem of acceptance to advanced technology solutions is not new and exists because individual stakeholders are resistant to change. In such situations it is critical that the developers of the system clearly outline the cost and benefits of implementing the new system. Moreover, it is critical that developers of PDM/EDM solution develop a cohesive strategy that fits into the overall business strategy for aircraft maintenance organizations that is well aligned with the business strategy. Thus, it is imperative for developers to conduct a detailed cost benefit analysis and explain to both the users and management as to how it will make them both become more effective and efficient. Specifically, in the aircraft maintenance environment it is critical for developers to explain how implementing a PDM/EDM strategy will lead to improved aviation safety and improved compliance/adherence to regulations and procedures.

Despite the high level of acceptability for the prototype system and the high-level of user satisfaction scores obtained for the prototype system, implementing EDM/PDM in the aircraft maintenance environment is not a simple straightforward exercise. Major barriers must be overcome to implement a PDM based solution. Realizing the existence of these barriers as well as the specific interventions that are necessary to overcome these barriers, future practitioners can more efficiently embark on PDM implementation. Moreover, others can use the lessons learned from this research before embarking on a similar venture. The major barriers/issues to implementing PDM in the aircraft maintenance environment are listed below.

Organizational Culture: Often the users of PDM themselves become barriers to change by wanting to retain the status quo. Implementing PDM, requires substantial change in an organization, the culture has to be one that can deal with such change effectively. The resistance to change, within an organization, can come from both the top management as well as the users of the system. Reasons for such resistance can include the following:

- the lack of awareness of the technology that is available,
- uncertainty about the maturity and robustness of the technology,
- confusion between the capabilities and limitations of the various systems,
- concerns about PDM integration with existing system,
- management fear of committing to a potentially all pervading cross functional system,
- management's philosophy that their problems are unique and can not be resolved using COTS EDM/PDM systems.

Integration: For PDM implementation to be successful in the aircraft maintenance environment, it needs to be smoothly integrated with existing systems. Specific problems associated with integration are: technical problems in migrating data from old to new systems, ability of the PDM system to effectively and efficiently communicate with existing system, ability to retain data integrity as it flows through the system. Faulty implementation of PDM can create "islands of automation" wherein the needs of one or more departments are satisfied while the strategic goal of the entire organization is not met.

Training: Successful implementation and acceptance of the EDM/PDM system is only possible following proper training of the user population. This training needs to be completed before the system is made available to the user population and before the final roll out of the system. In addition to training, system developers need to clearly plan for future technical support needs of the user population.

System Development: Although COTS are mature for use in developing a host of PDM based solutions. The development of fully functional systems still necessitates the use of professional IT personnel.

Hardware and Software Problems: Despite the successful implementation of the prototype system, there are specific issues related to hardware and software that need to be resolved before one can embark upon a successful PDM implementation in the aircraft maintenance environment, these include:

- Electronic approval process. Although the FAA approves electronic approval process, there are no detailed standards on how this process should be implemented in the aircraft maintenance environment. The aircraft maintenance industry can look for guidance to the e-commerce industry to establish these detailed standards.

- Data Security: Each organization needs to resolve how users with different levels of access to the system will share data.

- Networking: For a truly successful implementation of PDM/EDM it is important that computers are properly networked.

- Backup Systems and Procedures: System developers need to have procedures in place in situations when access to systems is not possible.

The successful implementation of the existing prototype system shows that state of the market is that many commercial of the shelf systems are now available and that they are maturing rapidly with a high degree of user satisfaction. It is critical to select the appropriate COTS system so that it seamlessly integrates with other existing systems. Organizations have often reported problems with EDM/PDM implementations and delayed rollouts because of inappropriate COTS software selection and poor planning. Successful PDM/EDM solutions with minimum hardware/software problems can be obtained only through phased implementation that includes: (1) understanding business process and user needs, (2) detailed understanding of existing document management systems and existing software/hardware, (3) managing business and organization change, (4) prototype development (5) testing and (6) full scale development and implementation.

Commitment to Implementation: To achieve the maximum possible benefit, aircraft maintenance organizations considering PDM must take the time to understand and plan the PDM implementation. Maintenance organizations must also be fully committed and involved from the highest levels of management. It is only when resources are committed with support and attention to planning, PDM can help organizations more effectively manage their data.

9.6 CONCLUSIONS

This research has demonstrated the successful implementation of a prototype EDM/PDM system for a representative aircraft maintenance process. The research project showed that a PDM based solution improved the effectiveness and efficiency of a specific process in the aircraft maintenance environment over an existing manual system. This in turn has direct impact on improving the safety and reliability of aircraft maintenance operations. The specific advantages of implementing a PDM based solution applied to the work card creation process in the aircraft maintenance environment are as follows:

1. improved efficiency and effectiveness,
2. data made available to the right person at the right time,
3. reduced costs because of improved efficiency,
4. electronic approval and increased data integrity and
5. superior record keeping, and
6. ability to integrate with other electronic systems.

Although, the above benefits are applicable to the representative process these can be extended to similar processes within the aircraft maintenance environment. Furthermore, by employing commercial off-the-shelf software systems PDM solutions can be developed faster and cheaper. The relatively low cost of COTS PDM/EDM software will enable aircraft maintenance organizations with limited budgets, to implement PDM based solutions. Once implemented correctly, PDM solutions have the potential to improve the integrity of various aircraft maintenance processes and ultimately aviation safety. However, it is important to realize that technology solutions are driven by business needs, where the functionality and features of any particular solution are in line with the objectives of the implementation.

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APPENDIX A - Definitions

The researchers (unless Galaxy paid for the project) created the software prototype specifically for the planning office in Hanger 8, Lockheed-Martin, Greenville, SC. The software is designed to automate or lessen the task load associated with service order, work deck creation. As is characteristic of many professions, the planning office possesses many area or company specific names and procedures. A list of definitions follows:

Card locator - A form included with each work card for the purpose of location audit. When the work cards are used on the hanger floor, the maintenance crew members must check out each specific work card, complete the work and then check the work card in. This process is recorded on the card locator form with the name of the crew member and the time of check in or check out. The procedure also aids in time on task analysis.

Deck - All of the work cards required for the current service order.

Kit materials A list of all parts, quantity of parts, part numbers, required for a specific procedure. This requirements – list is included with the relevant work card.

Reference – A footnote noting the existence of reference text contained in the work card.

Reference text – Relevant documentation pertaining to the work card procedure. Currently the reference material is contained in non-electronic manuals. The manuals span several volumes of large books. Some references include graphics, as well as text.

Service order – The service order is a reference number given to the aircraft and the current operation(s). The service order number is obtained from the administration office.

Stamp – Each employee carries a small (size varies from person to person) metal stamp of his or her initials and area. The stamp is used to check off a procedure after completion, to approve a task, to QA a specific action.

Tally sheet – A list of all of the work cards contained in a deck.

Work card – A form that details specific procedures of a specific operation. For instance, the work card might detail the procedure to install the nose radome (see Appendix G). The form includes the aircraft serial number, the service order number, the document revision number and date, all references and graphics, and all procedural steps.
Also called Work Instruction

APPENDIX B - Task Outline

APPENDIX B TASK OUTLINE

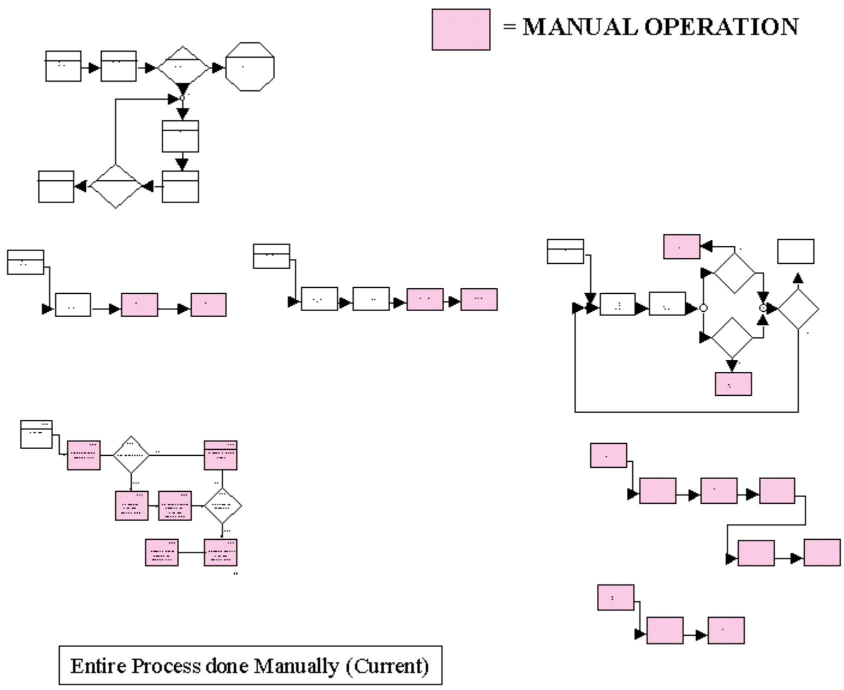
		NOW	WITH EDMS
1.0.0	**Receive Tail Number and Work Request from Customer**		
1.1.0	Customer calls with Tail Number and Work Request		
1.2.0	PD Looks up Serial Number	MANUAL	AUTOMATIC
1.3.0	PD Sends Information to Finance Dept.	MANUAL	EDMS WORK FLOW
2.0.0	**Receive Bar-code Number from MIS**		
2.3.0	PD receives Bar-code number via modem	MANUAL	EDMS WORK FLOW
2.4.0	PD Prints Bar code on label	MANUAL	AUTOMATIC
5.0.0	**Create Work Card Stack**		
5.1.0	Look up Work Card by Work Instruction No.	MS WORD	EDMS SEARCH
5.2.0	Enter Serial No. And Tail No. On Work Card	MS WORD	AUTOMATIC
5.4.0	Append References to Work Card	MANUAL	AUTOMATIC
5.4.1	*Search - Find references on Micro-fiche*	*MANUAL*	***ELIMINATED***
5.4.2	*Print copy of reference*	*MANUAL*	***ELIMINATED***

TASK OUTLINE (continued)

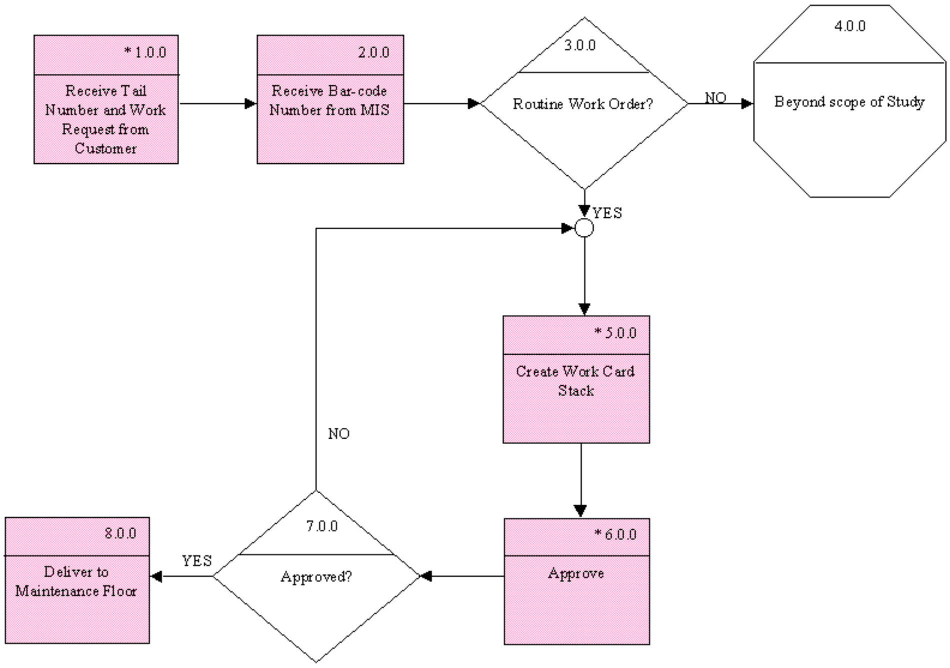
		NOW	WITH EDMS
5.6.0	Append graphics to Work Card	MANUAL	AUTOMATIC
5.6.1	*Count the number of required graphics*	*MANUAL*	***ELIMINATED***
5.6.2	*Print blank work card pages equal to number of graphics*	*MANUAL*	***ELIMINATED***
5.6.3	*Make copy of graphics from service manual on Xerox*	*MANUAL*	***ELIMINATED***
5.6.4	*Tape or glue graphics to blank work card pages.*	*MANUAL*	***ELIMINATED***
5.6.5	*Make copy (Xerox) of new page*	*MANUAL*	***ELIMINATED***
6.0.0	**Approve Stack**		
6.1.0	Send stack to QA	MANUAL	EDMS WORK FLOW
6.2.0	QA Stamps approval	MANUAL	DIGITAL
6.3.0	QA sends stack to PD	MANUAL	EDMS WORK FLOW
8.0.0	**Deliver to Maintenance Floor**	**MANUAL**	EDMS WORK FLOW
TOTAL TIME		**32 - 40 hrs**	**6 hrs (estimate)**

Planning Department Work Card Task Process

Current Process

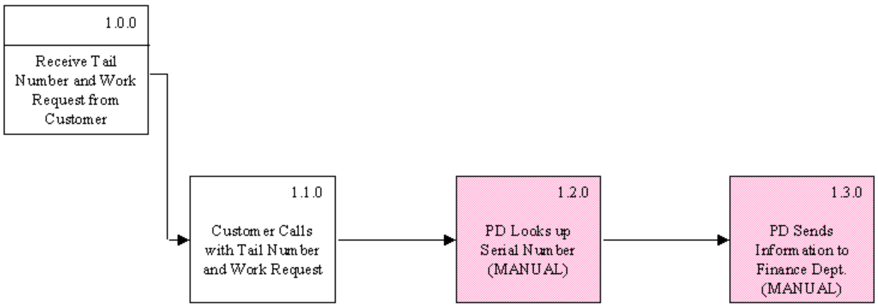


Top Level Tasks

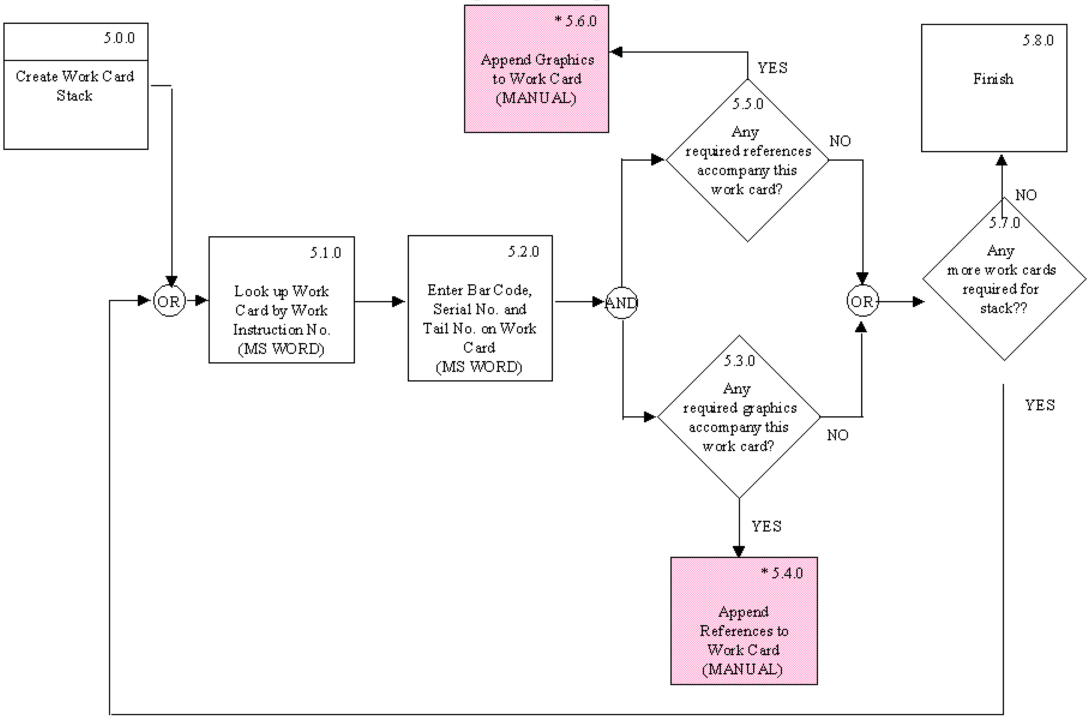


* More detailed flow diagram following.

Second Level Tasks
Detailed Flow Diagram of Top Level Task 1.0.0

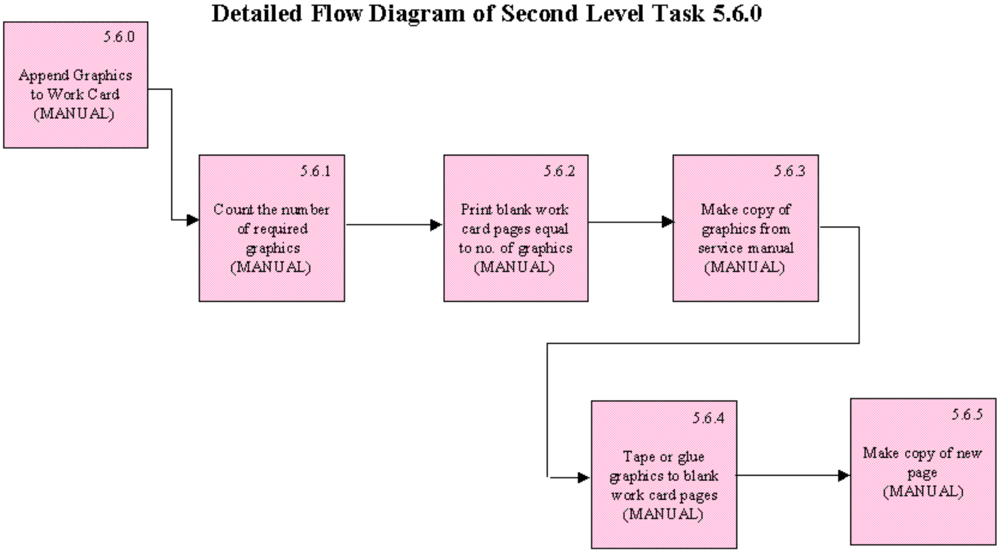


Second Level Tasks
Detailed Flow Diagram of Top Level Task 5.0.0

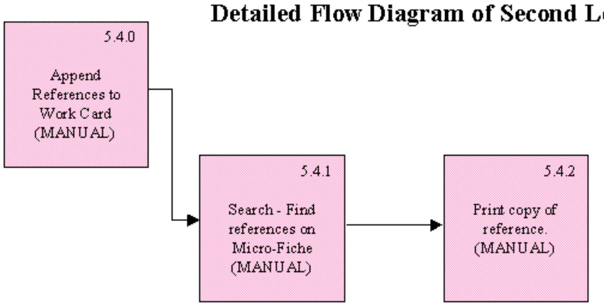


* More detailed flow diagram following.

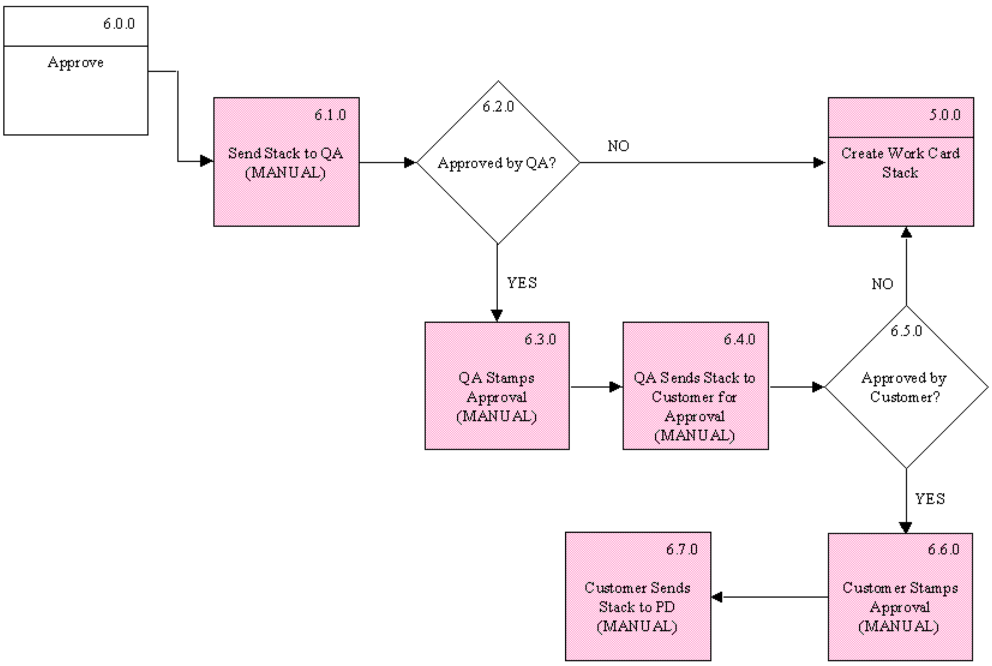
Third Level Tasks
Detailed Flow Diagram of Second Level Task 5.6.0



Third Level Tasks
Detailed Flow Diagram of Second Level Task 5.4.0

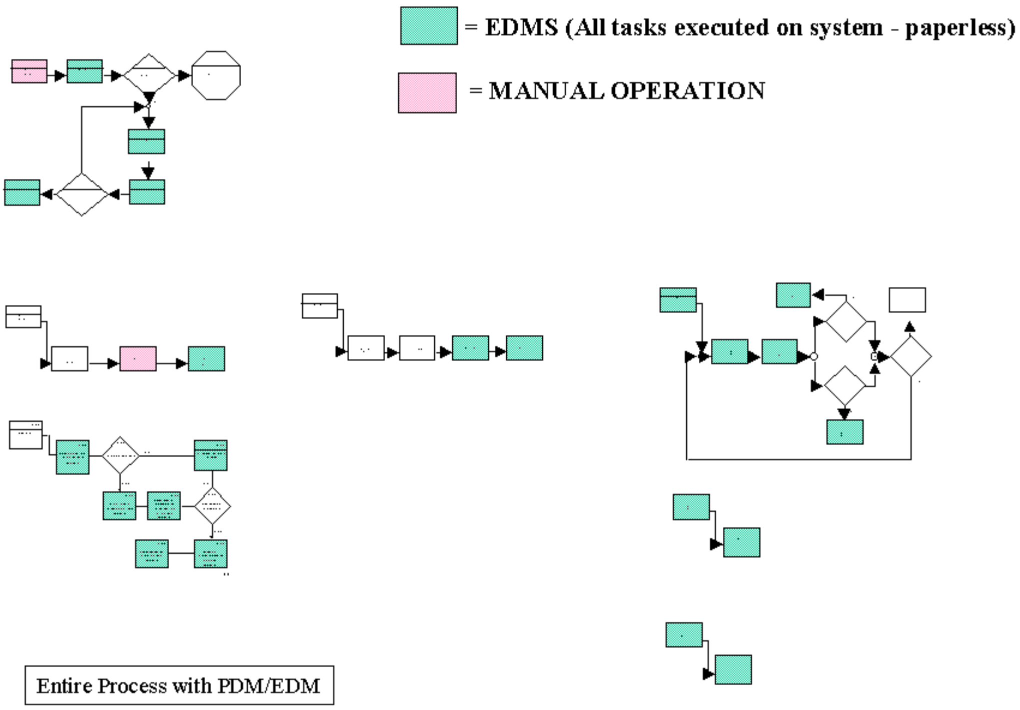


Second Level Tasks
Detailed Flow Diagram of Top Level Task 6.0.0

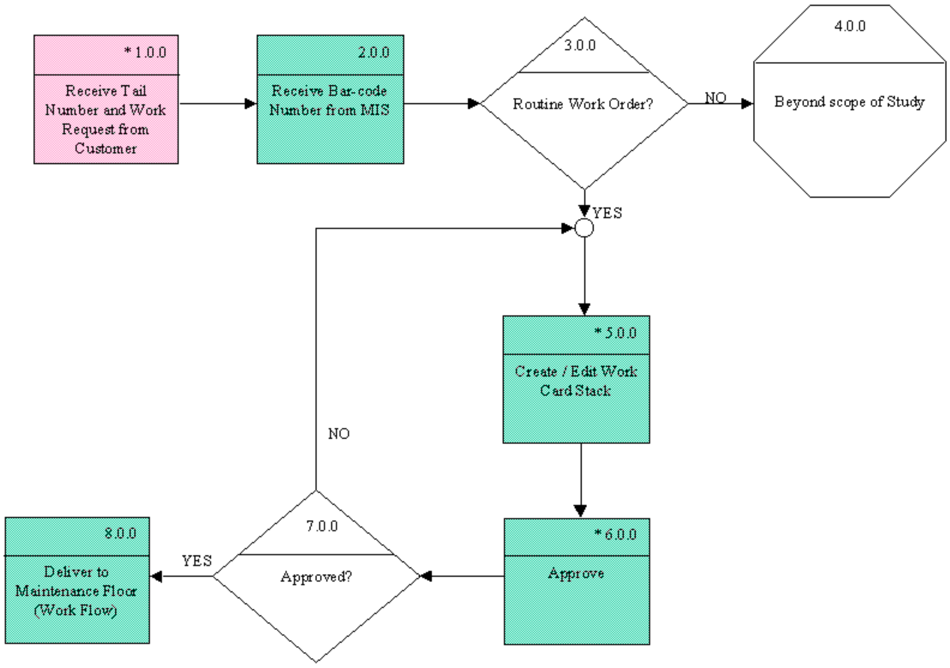


Planning Department Work Card Task Process

With Process Data Management / Electronic Data Management System (PDM/EDM)

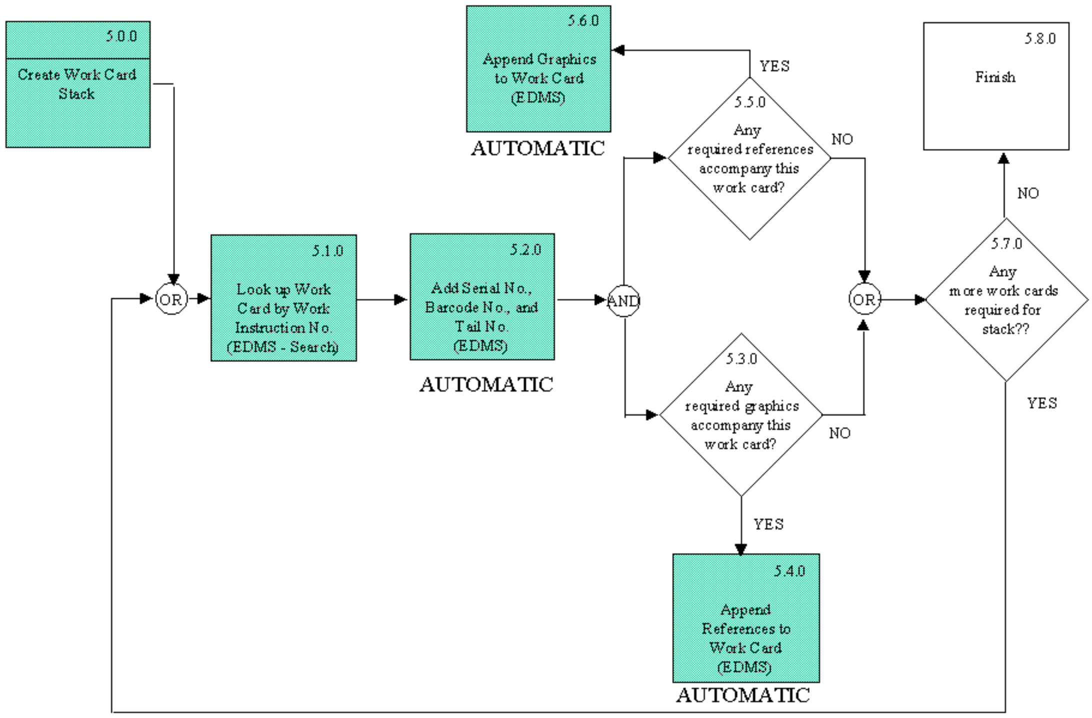


Top Level Tasks

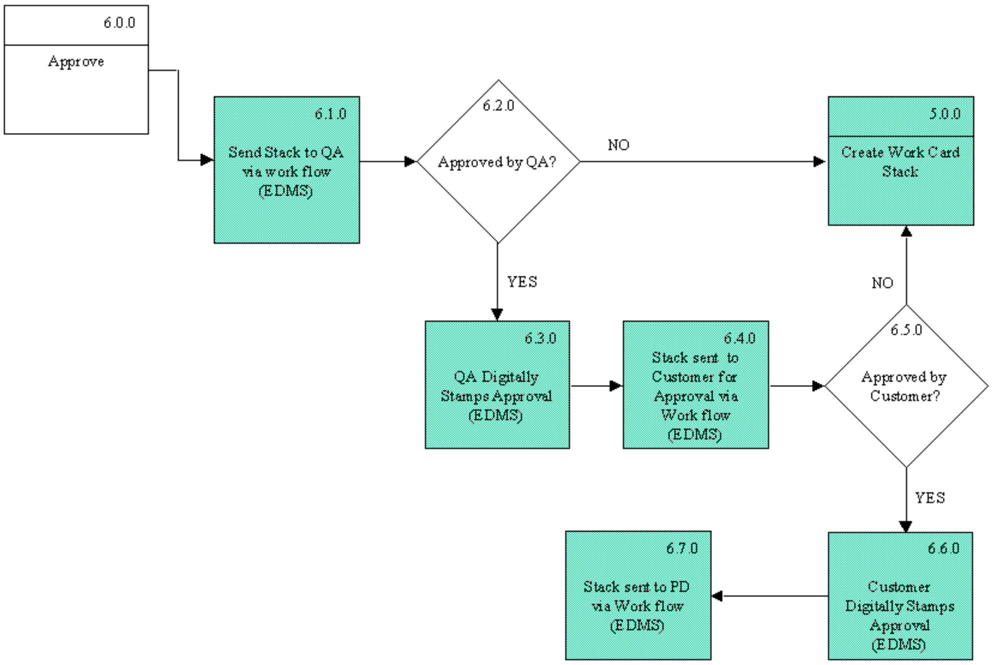


* More detailed flow diagram following.

Second Level Tasks
Detailed Flow Diagram of Top Level Task 5.0.0



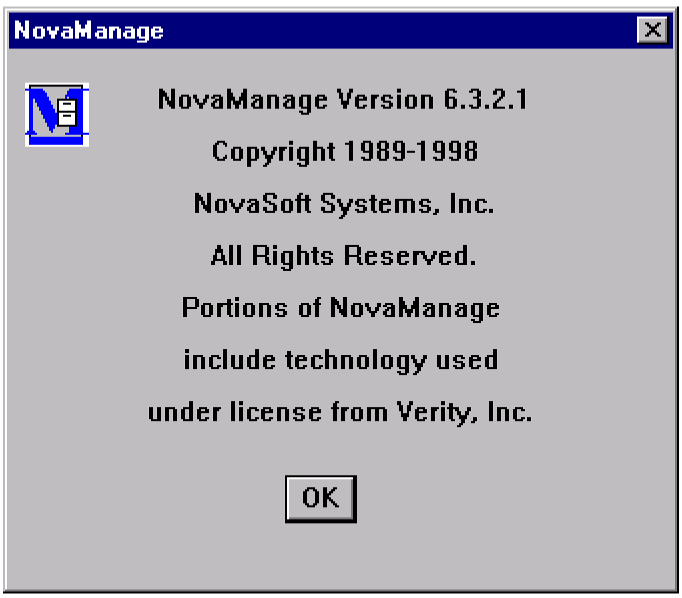
Second Level Tasks
Detailed Flow Diagram of Top Level Task 6.0.0



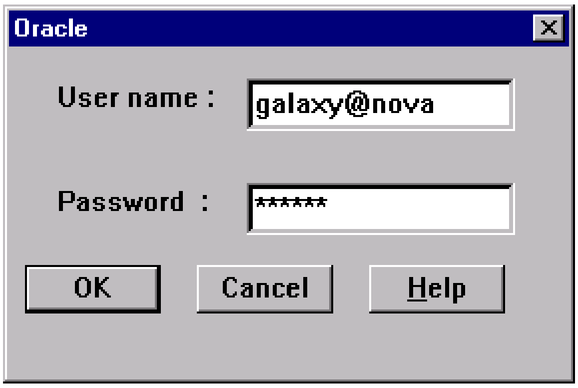
APPENDIX C

1. Open and Login

After double-clicking the NovaManage icon, the following screen will appear. Simply click on the “OK” button to move on.

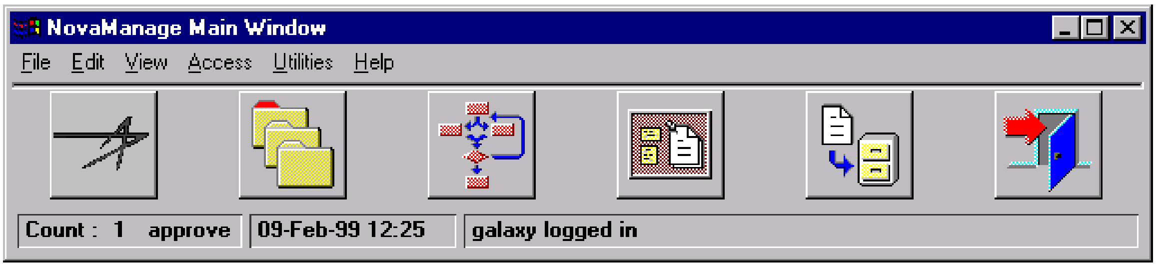


Log on using the username galaxy@nova and the password “galaxy”.

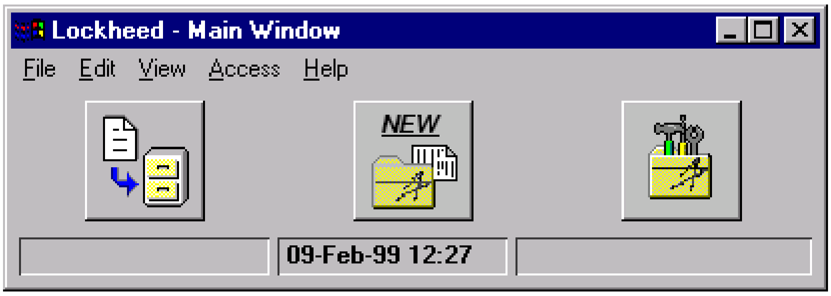


2. General operations.

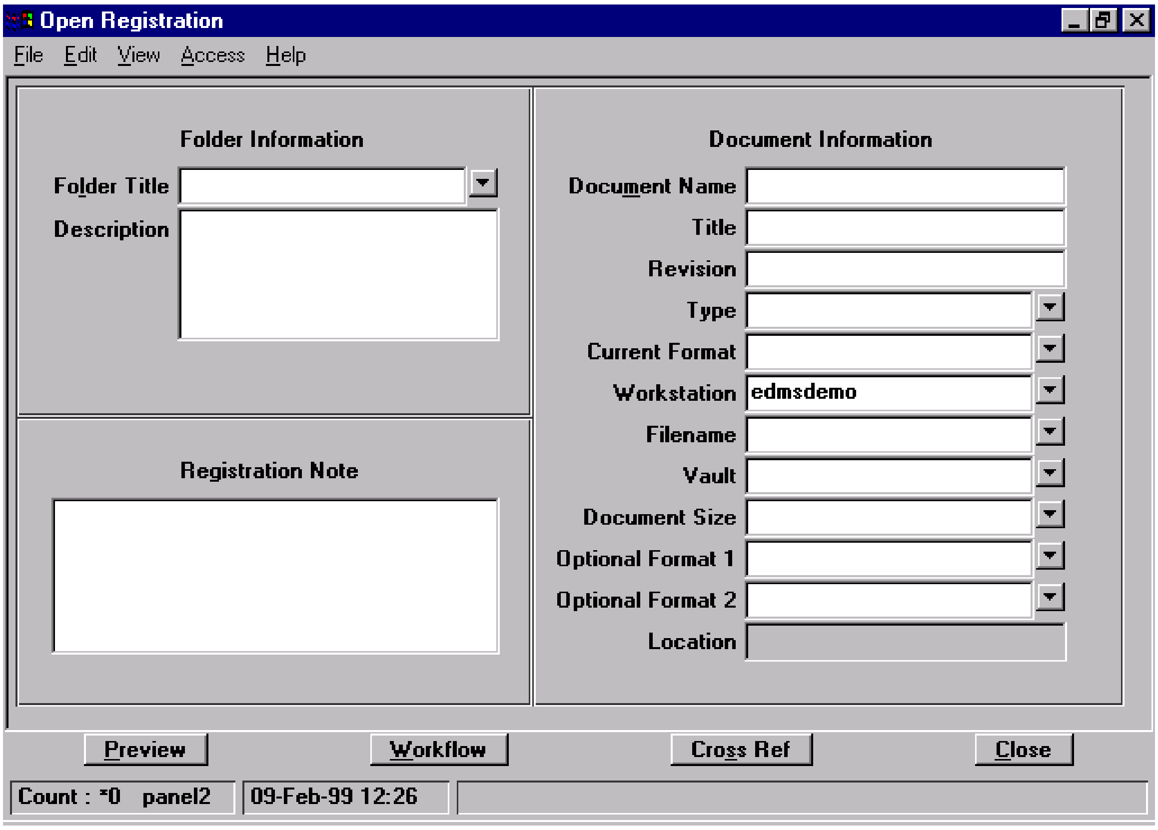
Once you have logged on, the following screen will appear. The first icon/button is for Lockheed-related operations. Click on this button.



Once you have clicked on the Lockheed icon/button, the following screen will appear. The icon/buttons correspond to Document Registration, New Service Order, General Information. The first button, Document Registration is used to place any document (work card, kit request form, card locator, etc.) into the system.



After clicking this button, the following window appears.



Click the button next to the folder field. A window will display folders (directories) within the system. Choose the folder where you want to place the document. After a folder is chosen, a "Release" button will appear at the bottom of the window.

In the Document Name field, type the name of the document. For work cards, use the work instruction number. Use the same name for title.

In the Revision field, type either "A" or "1", unless it is a changed document. In that case type "B" or "C" or "2" etc.

The Document Type is probably going to be "Document" and the Format will be "Word".

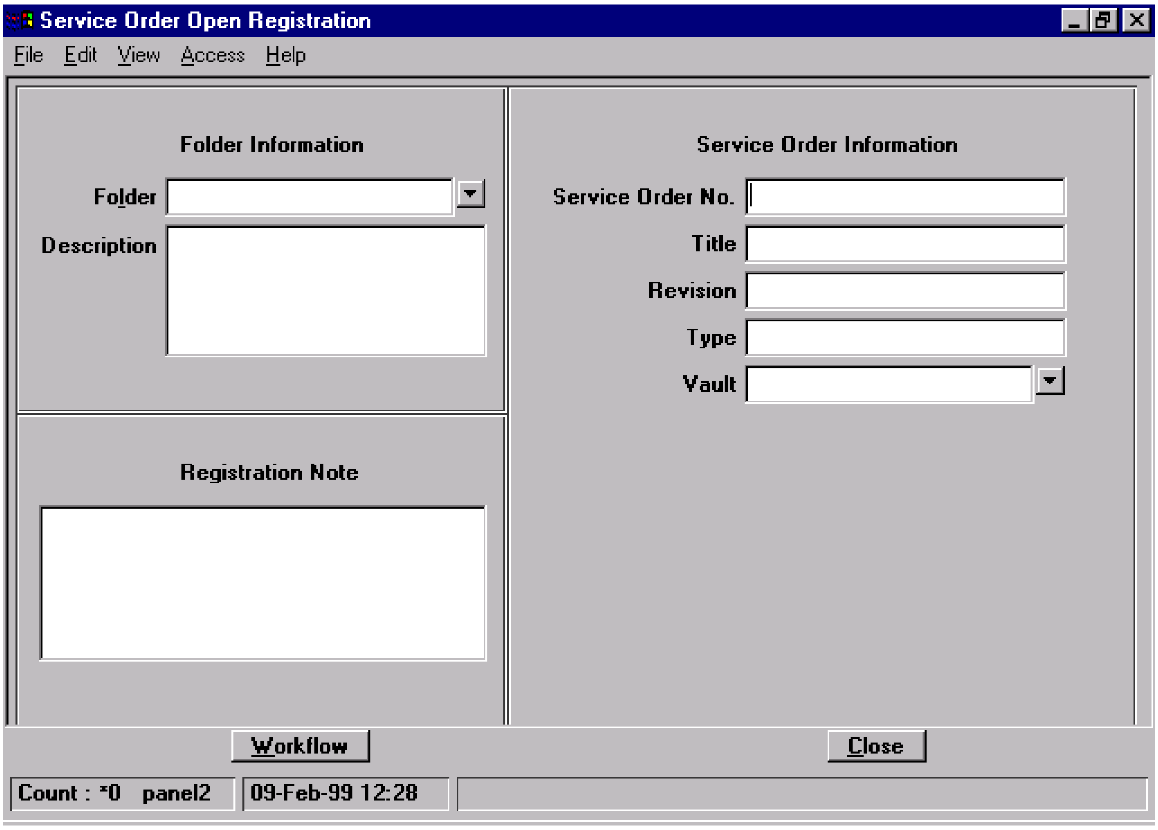
In the Filename field, use the button next to the field and find the actual document on the hard drive.

In the Vault field, select or type "EDMSDemo".

Now press the "Release" button.

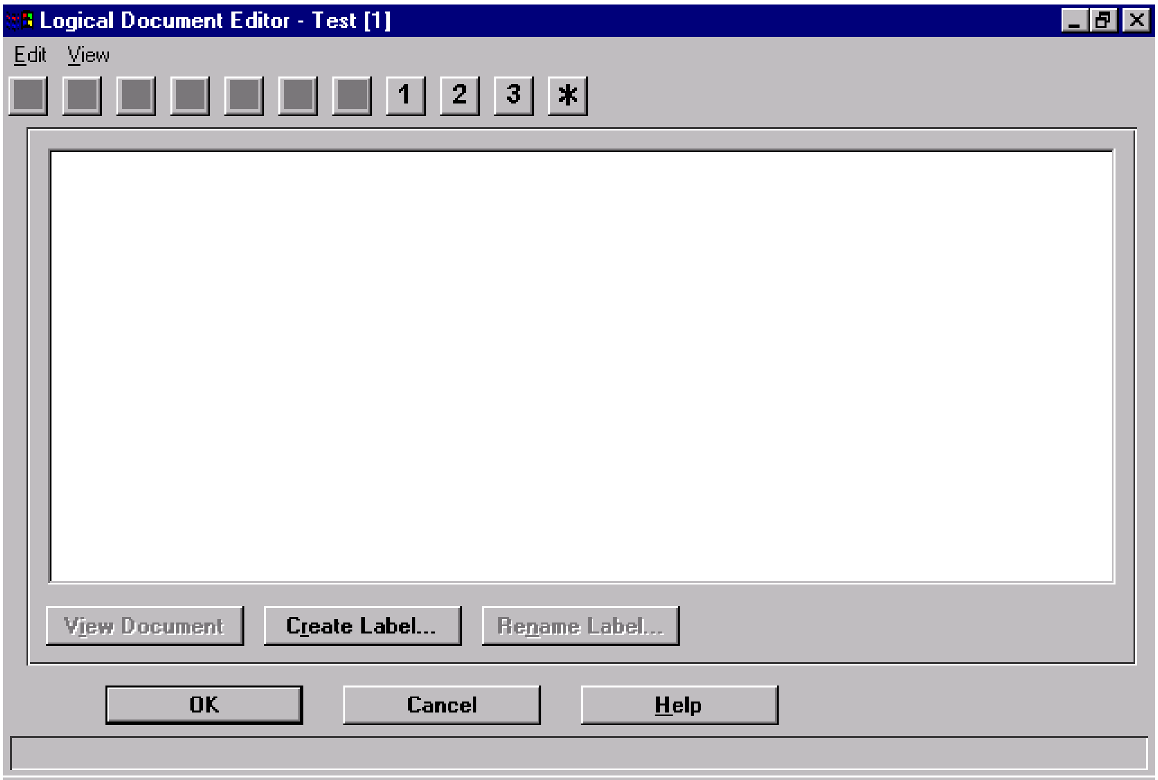
Close the window.

Once all of the required documents are in the system, a service order can be created. On the Lockheed – Main Window, press the center button to create a New Service Order. The following screen will appear.

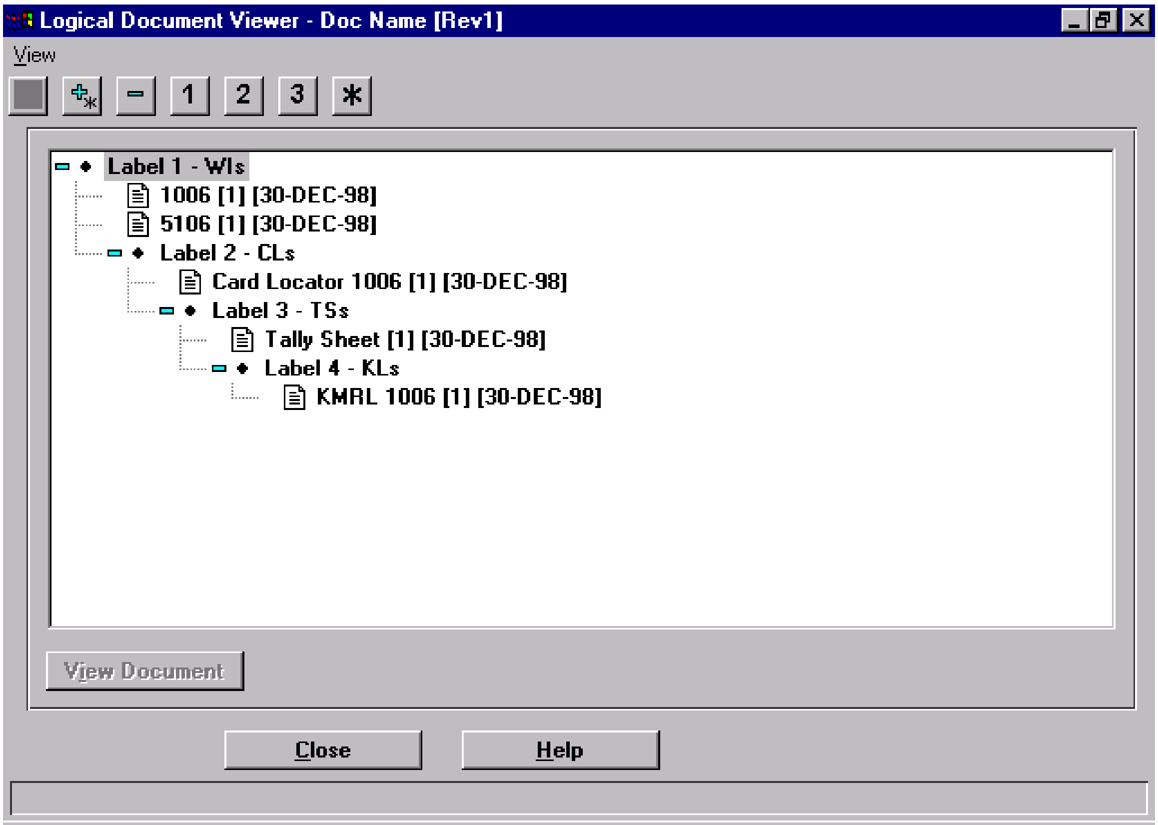


This window is similar to the Document Registration window. The difference is in the type of document. The Document type will only allow you to select "Logical". A logical document is simply a virtual collection of documents. In other words, it does not actually contain the documents, it merely "points" to them. This works similar to Microsoft Binder. In the Service Order No. Field, type the service order number. Select the "Work Flow" folder found in the "Registrar" folder.

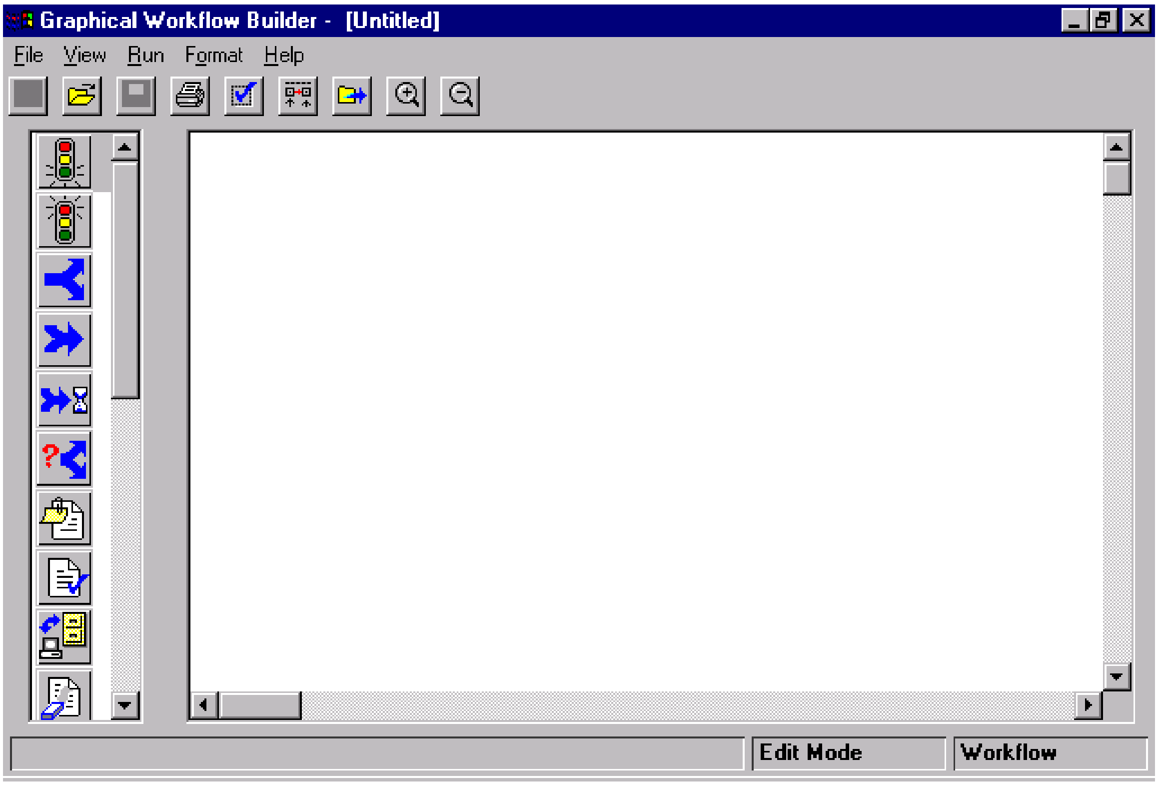
After completing the form, press the "Register" button (It will appear after you select the folder). The following screen will appear.



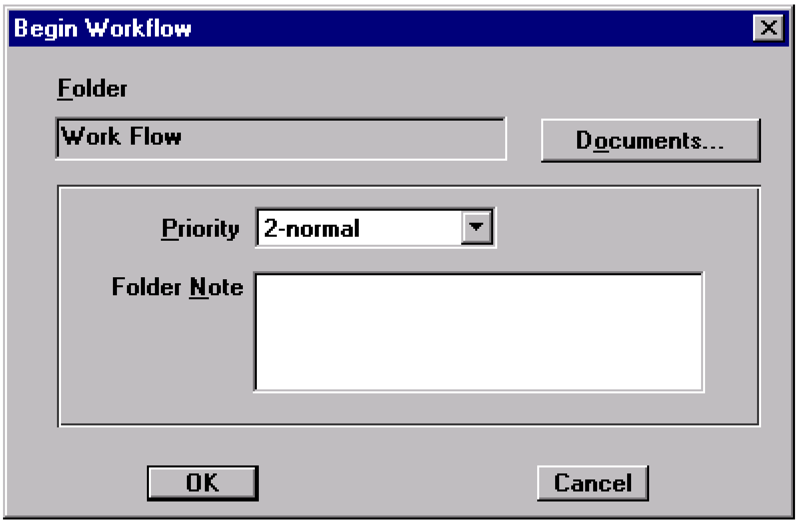
Leaving this window open, go to the Folders window by clicking the second icon button on the NovaManage Main Window. Open the folders containing your documents (work cards, card locators, etc.) and drag them into the Logical Document Editor window. You can add labels to help organize the files. Use the commands in the Edit menu to move the documents up or down in the window. After completing the window, select "OK".



Now, on the Service Order Open Registration window, select the "Workflow" button. The following window will appear.



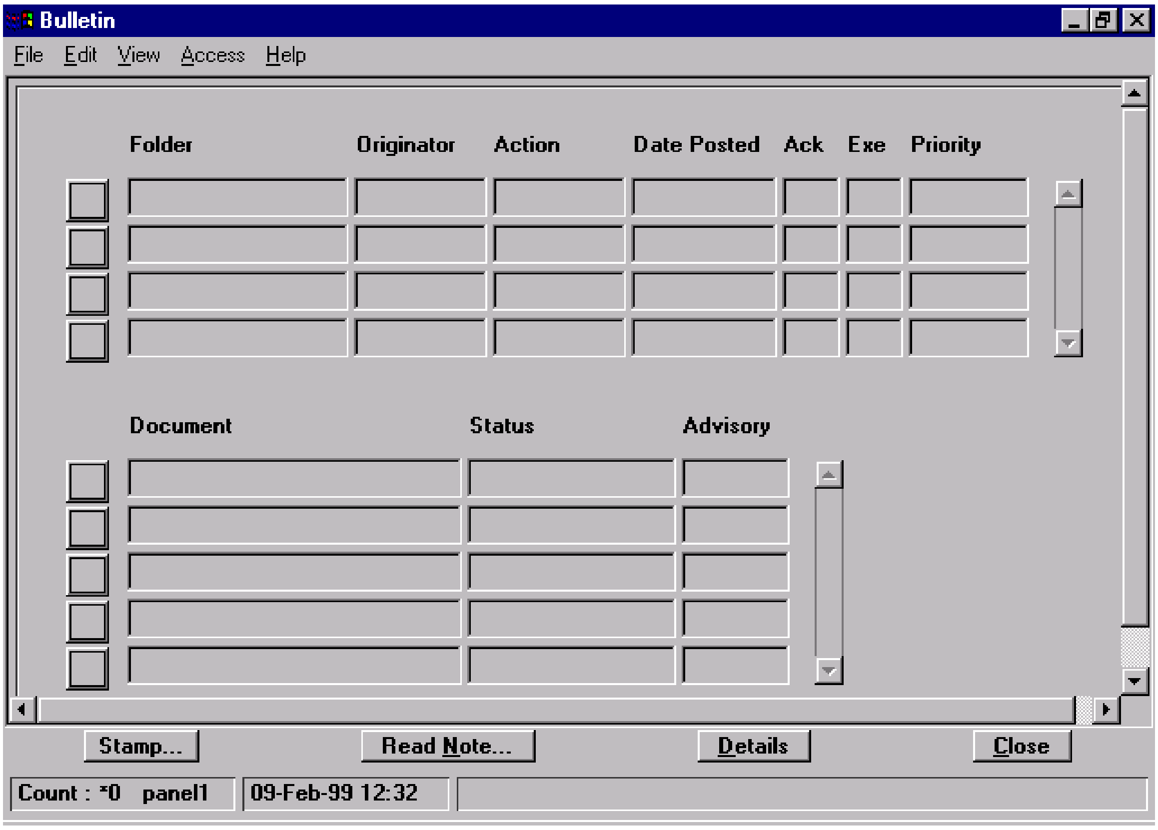
In the “File” menu, select “Open”. Only one file is listed. Select it and open it. In the “Run” menu, select “Begin...”. The following window will appear.



Select “OK” and answer “Yes” to the next dialog box.

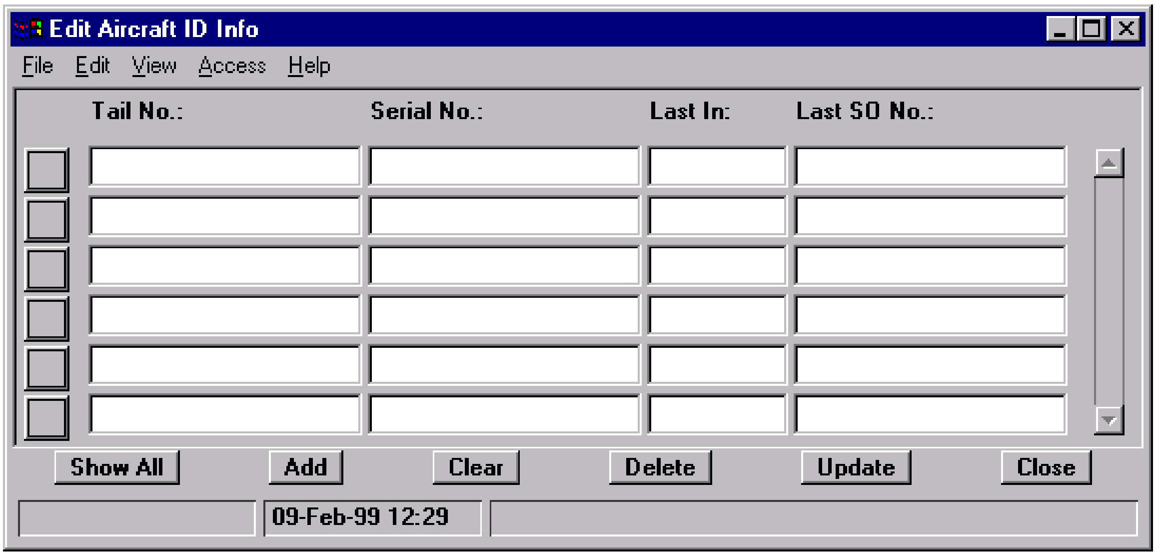
The work flow process will notify each person listed in the workflow of their responsibilities.

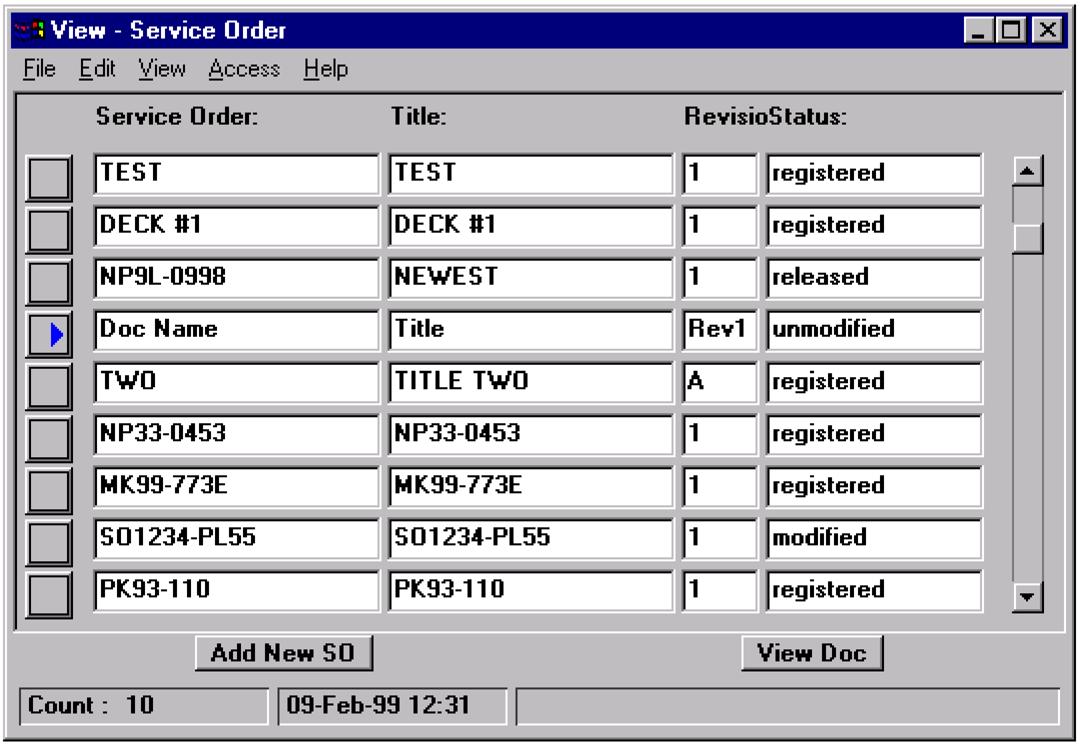
To view the status of the process, press the Bulletin icon/button (fourth button) on the NovaManage Main Window. The following window will appear.



At each point in the process that involves an approval, the stamp button will be used. This causes a window to appear asking for a password. When the password is entered, the step is complete.

The last button on the Lockheed Main Window is for information purposes. The Aircraft info window allows you to enter or view aircraft information. The Service order window allows you to view service orders that have completed the workflow process.





APPENDIX D - **Survey**

Please take some time to complete the survey. Your responses will help us in evaluating the tool and developing future enhancements. **All information will be kept confidential and coded so that no one can trace the responses to any specific individual**. Thank you for your time and participation

Name__________________________ Gender: Male Female

Current Job Title_________________

Years on the Job__________________

Educational Experience (highest degree)_____________

Indicate you computer experience (circle one)

- Extremely Proficient
- Proficient
- Average
- Below Average
- Poor

Response numbers only go from 1-5

Note: Please indicate your response by circling numbers 1-5 for each statement listed below.

1. I feel the material in the tool was well laid out and legible.

1 2 3 4 5
Strongly Argree **Strongly Disagree**

2. The tool was extremely easy to use.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

3. The text and graphics were self-explanatory.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

4. With minimal training, others and I will be able to make full use of the tool.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

5. The tool can be easily adapted to help me in my job.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

6. With some modifications the tool will allow me to easily manipulate existing documents (text and pictures).

1 2 3 4 5
Strongly Agree **Strongly Disagree**

7. The tool will be extremely useful in my current job.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

8. The tool will reduce the time for delivering workcards to the hangarfloor.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

9. The tool will help improve my productivity.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

10. The version control component of the tool will significantly aid in the audit process.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

11. I think the tool should be deployed by the company.

1 2 3 4 5
Strongly Agree **Strongly Disagree**

12. The tool will have a broad level of acceptability within my company.

1 2 3 4 5
Strongly **Strongly**

Agree Disagree

13. If this tool is made available, I will definitely use it.

1 2 3 4 5
Strongly Strongly
Agree Disagree

14. I feel computers have a very important role to play in improving our productivity by reducing paperwork through automation.

1 2 3 4 5
Strongly Strongly
Agree Disagree

15. I feel computers have an important role to play in the aircraft maintenance environment.

1 2 3 4 5
Strongly Strongly
Agree Disagree

16. Because of the reduced task load, I feel that I will make fewer errors.

1 2 3 4 5
Strongly Strongly
Agree Disagree

In the following questions, compare tool to the current 'hard copy' or paper method. Respond by circling the appropriate number.
1 = tool is much better 2 = tool is slightly better 3 = tool and current method are equal
4 = current method is slightly better 5 = current method is much better

17. The tool allows form, card, and document creation, edit, and approval without printing. I trust that the entire work deck is safe and secure.

1	2	3	4
Tool is Much better		**Tool and current Method are equal**	

18. The process of auditing past work history is relatively easy.

1	2	3	4
Tool is Much better		**Tool and current Method are equal**	

19. Changes made to existing forms or documents are traceable and well documented.

1	2	3	4
Tool is Much better		**Tool and current Method are equal**	

20. The approval process is quick and easy.

1	2	3	4
Tool is		**Tool and current**	
Much better		**Method are equal**	

21. Please estimate the number of hours required to achieve the work order task WITHOUT the program.

____

22. Please estimate the number of hours required to achieve the work order task WITH the program.

____

APPENDIX E

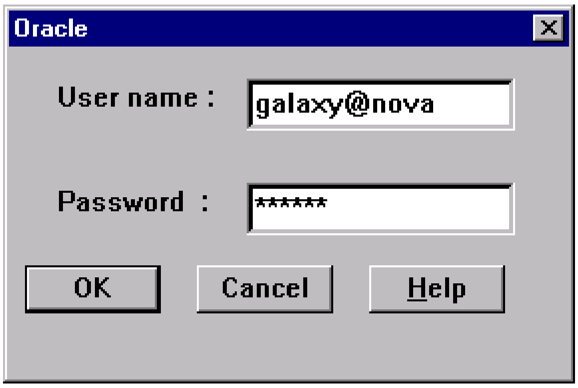
	Questions	Five Point	Scale	Mean Score
1	I feel the material in the tool was well laid out and legible.	**1**-Strongly Agree	**5**-Strongly Disagree	2
2	The tool was extremely easy to use.	**1**-Strongly Agree	**5**-Strongly Disagree	2
3	The text and graphics were self-explanatory.	**1**-Strongly Agree	**5**-Strongly Disagree	2
4	With minimal training, others and I will be able to make full use of the tool.	**1**-Strongly Agree	**5**-Strongly Disagree	2
5	The tool can be easily adapted to help me in my job.	**1**-Strongly Agree	**5**-Strongly Disagree	2
6	With some modifications the tool will allow me to easily manipulate existing documents (text and pictures)	**1**-Strongly Agree	**5**-Strongly Disagree	2.5
7	The tool will be extremely useful in my current job.	**1**-Strongly Agree	**5**-Strongly Disagree	2
8	The tool will reduce the time for delivering workcards to the hangar-floor.	**1**-Strongly Agree	**5**-Strongly Disagree	2.5

9	The tool will help improve my productivity.	**1**-Strongly Agree	**5**-Strongly Disagree	2.5
10	The version control component of the tool will significantly aid in the audit process.	**1**-Strongly Agree	**5**-Strongly Disagree	2
11	I think the tool should be deployed by the company.	**1**-Strongly Agree	**5**-Strongly Disagree	3
12	The tool will have a broad level of acceptability within my company.	**1**-Strongly Agree	**5**-Strongly Disagree	3
13	If this tool is made available, I will definitely use it.	**1**-Strongly Agree	**5**-Strongly Disagree	2
14	I feel computers have a very important role to play in improving our productivity by reducing paperwork through automation.	**1**-Strongly Agree	**5**-Strongly Disagree	1
15	I fell computers have an important role to play in the aircraft maintenance.	**1**-Strongly Agree	**5**-Strongly Disagree	1
16	Because of the reduced task load, I feel that I will make fewer errors.	**1**-Strongly Agree	**5**-Strongly Disagree	3
17	The tool allows form, card, and document creation, edit, and approval without printing. I trust that the entire work deck is safe and secure.	**1**-Tool is Much Better	**5**-Current Method is Much Better	2
18	The process of auditing past work history is relatively easy.	**1**-Tool is Much Better	**5**-Current Method is Much Better	2
19	Changes made to existing forms or documents are traceable and well documented.	**1**-Tool is Much Better	**5**-Current Method is Much Better	2
20	The approval process is quick and easy.	**1**-Tool is Much Better	**5**-Current Method is Much Better	1

21	Please estimate the number of hours required to achieve the work order task WITHOUT the program.	40hrs.
22	Please estimate the number of hours required to achieve the work order task WITH the program.	20hrs.

APPENDIX F - Window Behavior Document

Window 1.0.0 - Login



Process **Program checks User database for user name / password match.**

Display **Displayed automatically upon entry to system.**

1.1.0 Controls

1.1.1 Text Box - User Name

Function **User will type user name in text box.**

Characteristics font = Arial, 12 pt.
Background color = white
Foreground color = black

Acceptable input User name, followed by an @, followed by the name of the database.

User may also add a space then a forward slash then another space, followed by the password. If the username or database name are invalid, M1 or M2 will be displayed.

1.1.2 Text Box - Password

Function **User will type password in text box.**

Characteristics font = Arial, 12 pt.
Background color = white
Foreground color = black
Mask = “*”

Acceptable input Password. The password must be at least 6 characters in length and contain apha-numeric characters, as well as “&”, “$”, “!”. No other characters or spaces are acceptable. If the password is invalid, M1 will be displayed.

1.1.3 OK, Cancel, Help Command Buttons

Function **Follow Microsoft guidelines**

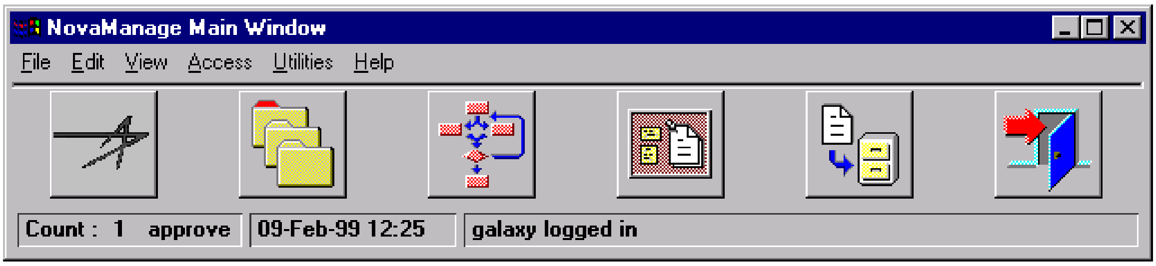
Characteristics font = Sans Serif, 10 pt.
Foreground color = black

1.2.0 Message Boxes

M1. "Username or password not found, please try again."

M2. "The database can not be found."

Window 2.0.0 Main Window



Process The window will display iconic command buttons used for navigation within the system. Depending on the privileges of the current user, the window will display from one iconic button to eight iconic buttons.

Modal/Modeless The window is modal. Closing the window exits the program.

Parent/Child Parent - Lockheed Main Window
Folders
Work Flow
Bulletin Board
Open Registration
Exit

Child - N/A

Note: The display is the standard display created by NovaSoft. The window is customizable. Due to time constraints, only the added or altered controls will be discussed.

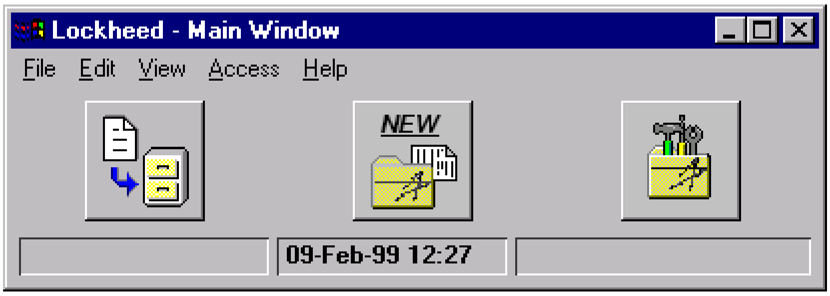
2.1.0 Controls

2.1.1 Iconic Command Button - Lockheed

Function User will depress button to enter custom windows.

Characteristics icon = Lockheed star logo

Window 3.0.0 - Lockheed Main Window



Process Depending on user priviledges, the window will display from one to 5 iconic command buttons.

Modal/Modeless Modeless. The window can be closed or opened without effecting other windows.

Parent/Child Parent - Open Registration
Service Order Open Registration
Tools / Info
Child - Main Window

3.1.0 Iconic Command Buttons

3.1.1 Open Registration

Function User will depress button to access the Open Registration window.

Characteristics This is a default NovaSoft iconic button.

3.1.2 Service Order Open Registration

Function User will depress button to access the Service Order Open Registration window.

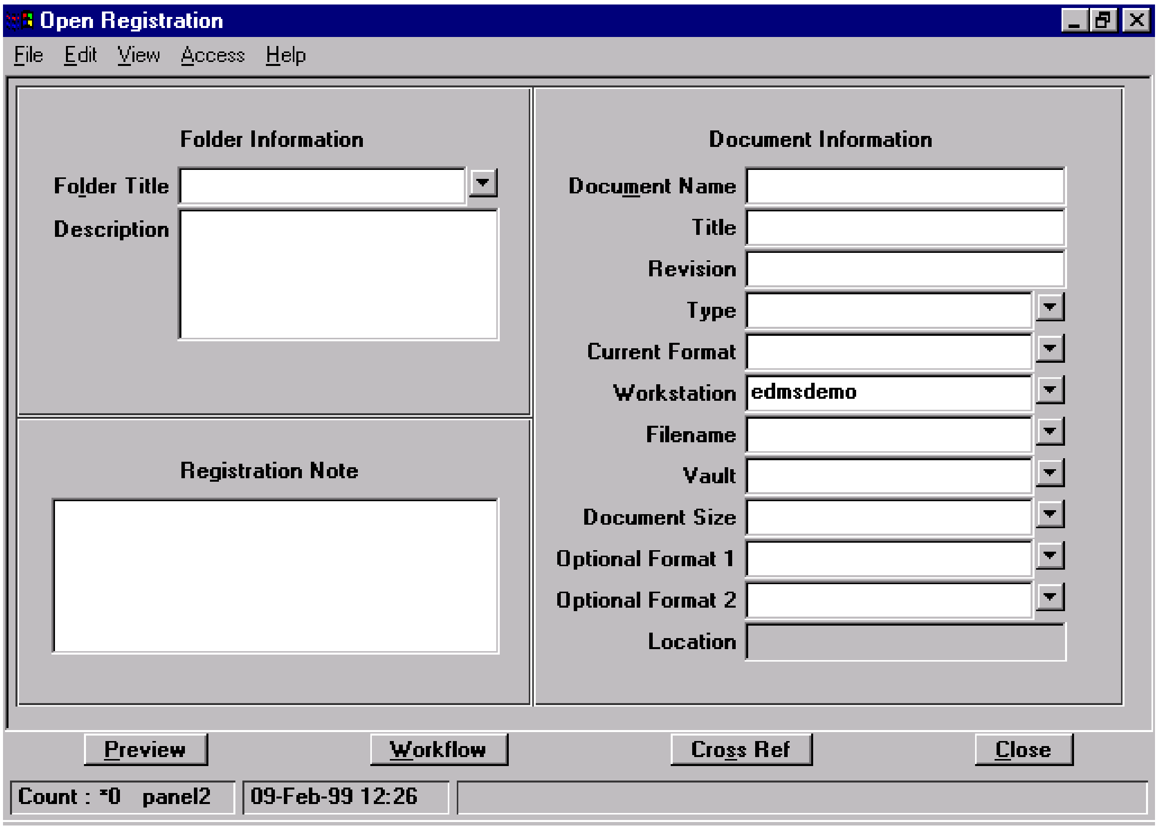
Characteristics icon = Folder with Lockheed logo; paper entering folder; text display of "New", underlined.

3.1.2 Tools / Info

Function User will depress button to access the Tools / Info window.

Characteristics icon = Folder with Lockheed logo; Tools extending from folder

Window 4.0.0 - Open Registration



Process **The purpose of this window is to enter documents into the system. This is a default NovaSoft window. Therefore it will not be discussed at its basic form.**

Modal/Modeless **Modeless. The window can be closed or opened without effecting other windows.**

Parent/Child **Parent - Document Preview**
Workflow
Cross Reference window
Child - Lockheed Main Window

Procedure **Click the button next to the folder field. A window will display folders (directories) within the system. Choose the folder where you want to place the document. After a folder is chosen, a "Release" button will appear at the bottom of the window.**

In the Document Name field, type the name of the document. For work cards, use the work instruction number. Use the same name for title.

In the Revision field, type either "A" or "1", unless it is a changed document. In that case type "B" or "C" or "2" etc.

The Document Type is probably going to be "Document" and the Format will be "Word". Other choices could be Image/gif, Drawing/AutoCAD, etc.

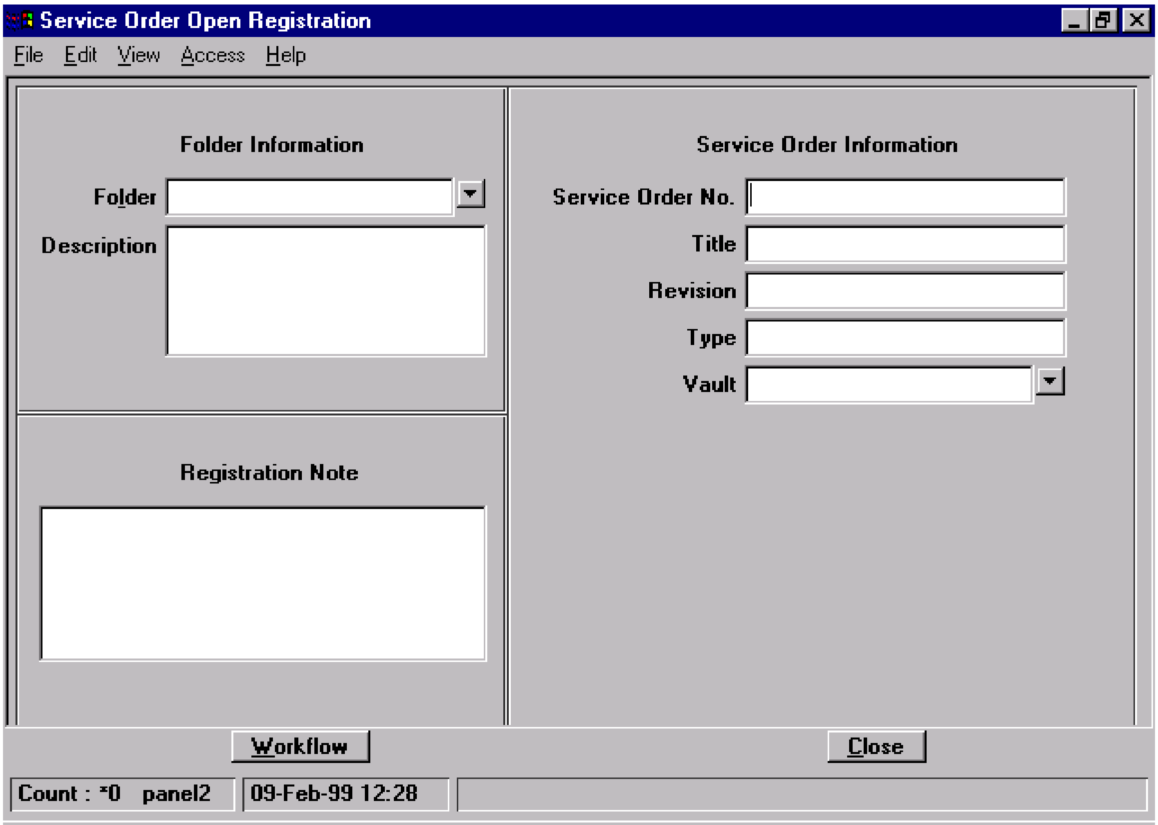
In the Filename field, use the button next to the field and find the actual document on the hard drive.

In the Vault field, select or type the vault name (e.g., "EDMSDemo").

Now press the "Release" button.

Window 5.0.0 - Service Order Open Registration

Once all of the required documents are in the system, a service order can be created. On the Lockheed – Main Window, press the center button to create a New Service Order. The following screen will appear.



Process **The purpose of this window is to enter service orders into the system.**

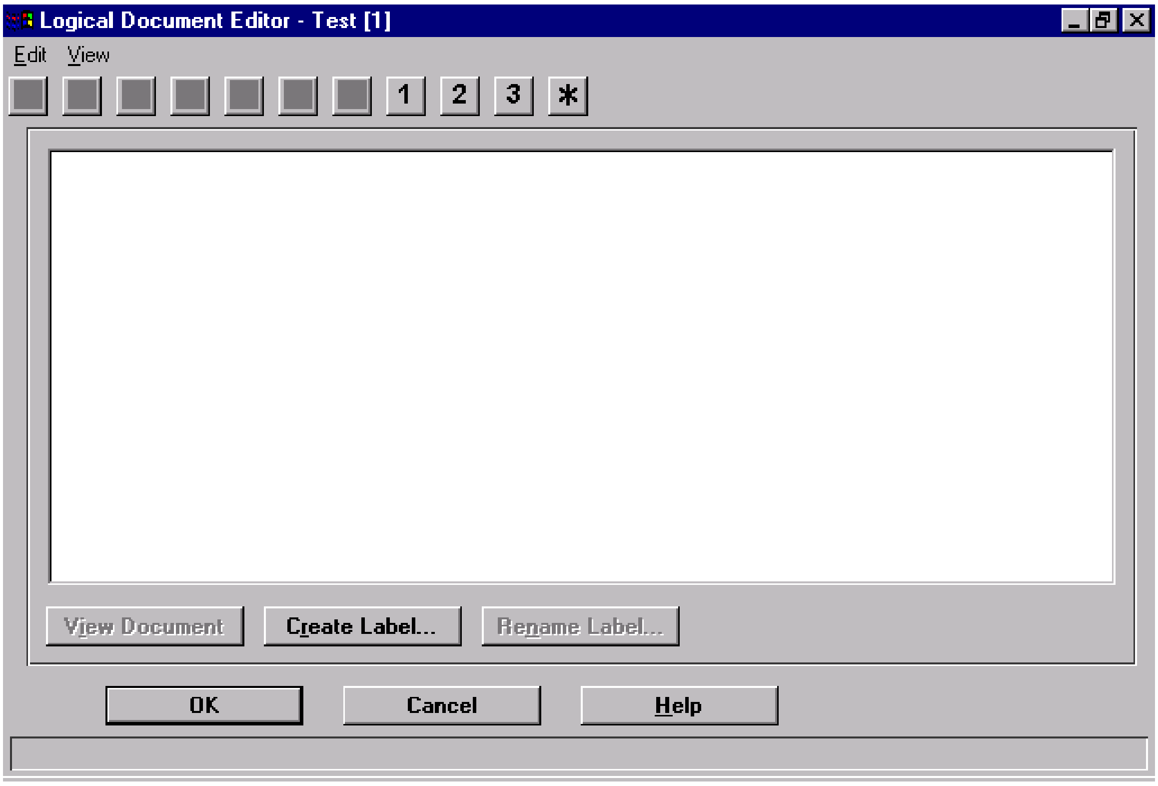
Modal/Modeless **Modeless. The window can be closed or opened without effecting other windows.**

Parent/Child **Parent - Workflow**
Register (Button disabled in above picture)
Child - Lockheed Main Window

Procedure and Notes **This window is similar to the Document Registration window. The difference is in the type of document. The Document type will only allow you to select “Logical”. A logical document is simply a virtual collection of documents. In other words, it does not actually contain the documents, it merely “points” to them. This works similar to Microsoft Binder. In the Service Order No. Field, type the service order number. Select the “Work Flow” folder found in the “Registrar” folder.**

Window 6.0.0 - Logical Document Editor

After completing the form, press the “Register” button (It will appear after you select the folder). The following screen will appear.

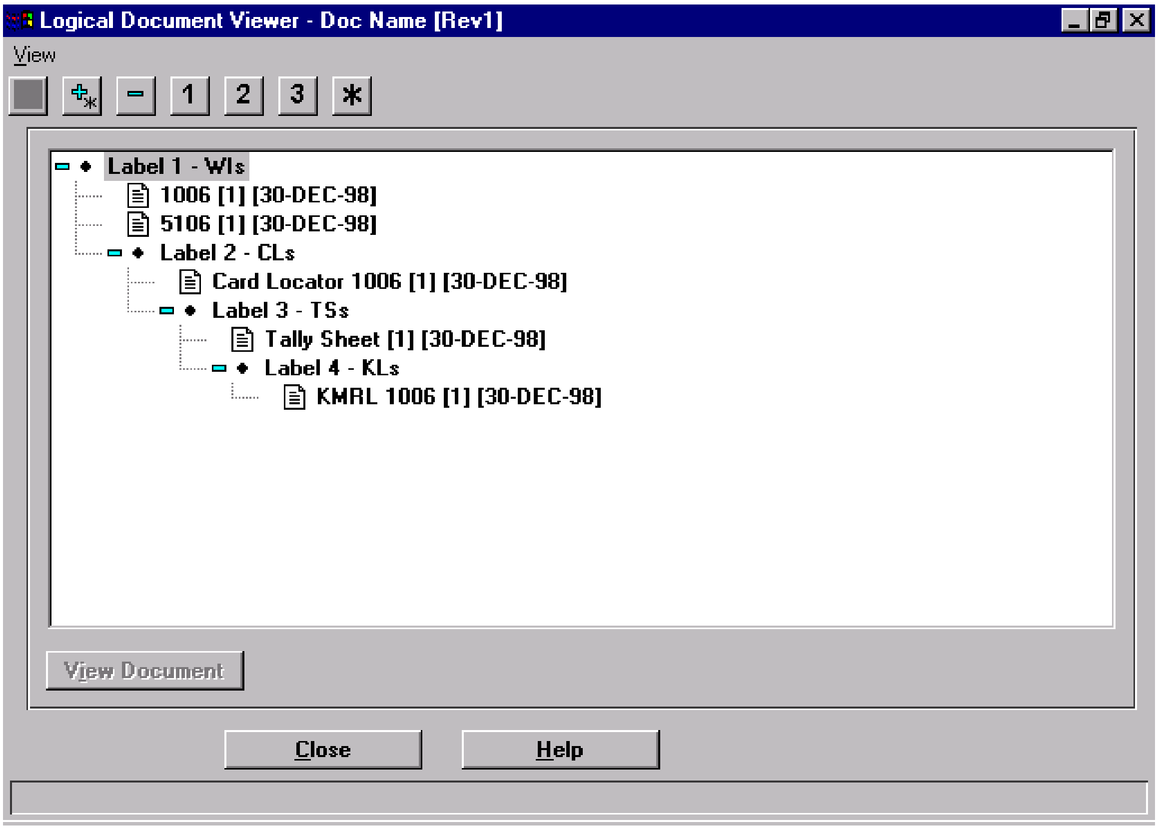


Process The purpose of this window is to enter documents into a virtual container. In other words, this window is used to place work instructions into a deck. This is a default NovaSoft window. Therefore it will not be discussed at its basic form.

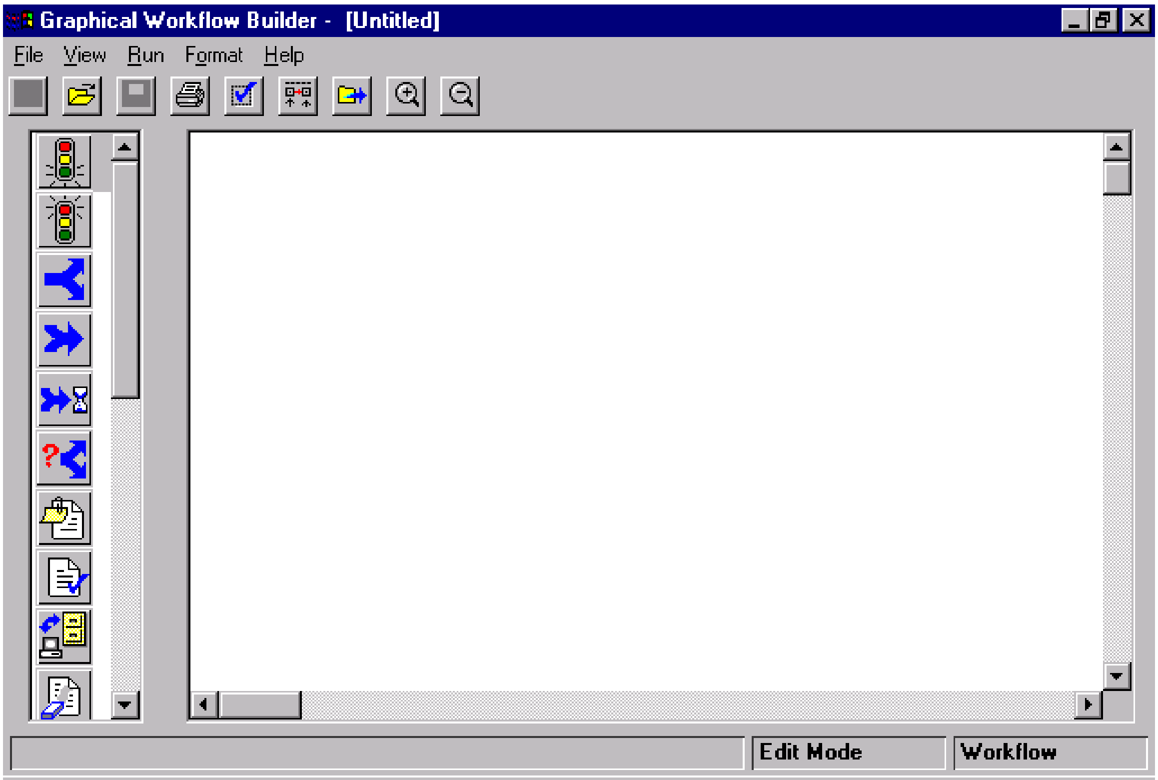
Modal/Modeless Modeless. The window can be closed or opened without effecting other windows.

Parent/Child Parent - Document Preview
Child - Service Order Open Registration

Procedure/Notes Leaving this window open, go to the Folders window (below) by clicking the second icon button on the NovaManage Main Window. Open the folders containing your documents (work cards, card locators, etc.) and drag them into the Logical Document Editor window. You can add labels to help organize the files. Use the commands in the Edit menu to move the documents up or down in the window. After completing the window, select "OK". A sample of a completed logical document is found below.



Window 7.0.0 - Graphical Workflow Builder

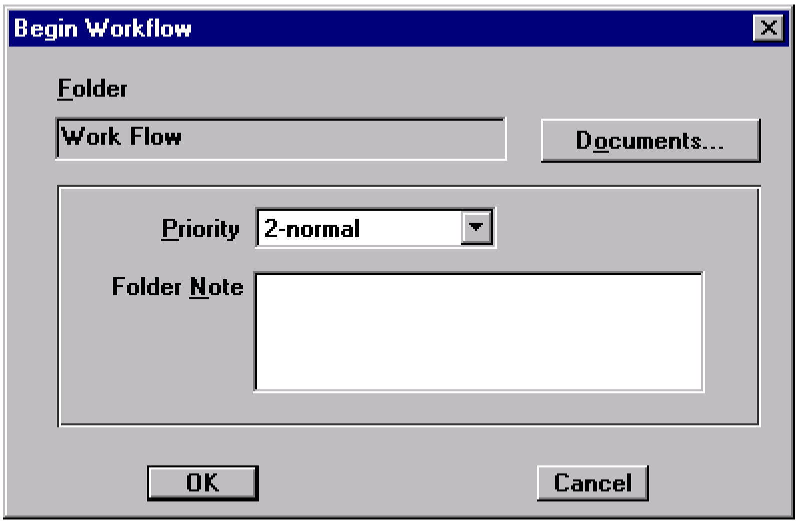


Process The purpose of this window is to select an appropriate, previously created workflow. When a workflow is opened and selected via the File/Open menu item, then below window will appear. This is a default NovaSoft window. Therefore it will not be discussed at its basic form.

Modal/Modeless Modeless. The window can be closed or opened without effecting other windows.

Parent/Child Parent - Service Order Open Registration
Child - N/A

Procedure/Notes In the “File” menu, select “Open”. Select the appropriate workflow and open it. In the “Run” menu, select “Begin...”. The following window will appear.

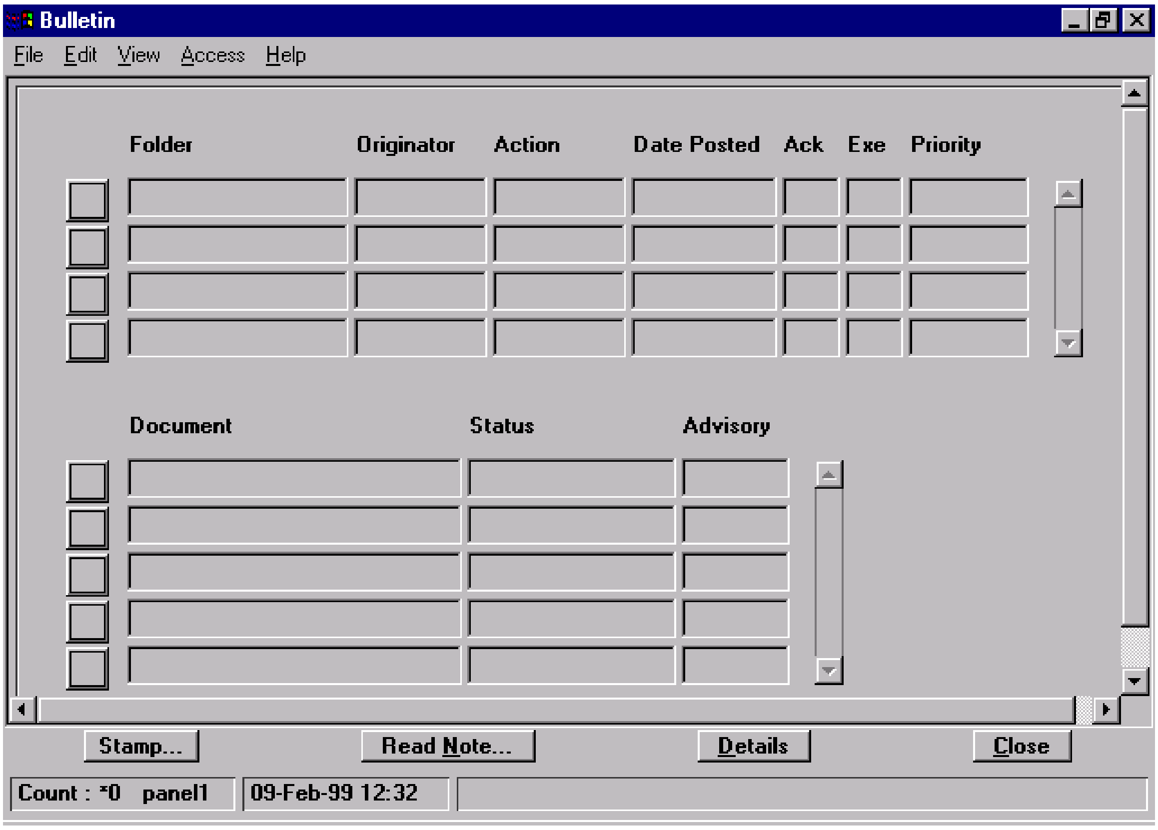


Select “OK” and answer “Yes” to the next dialog box.

The work flow process will notify each person listed in the workflow of their responsibilities.

Window 8.0.0 - Bulletin

To view the status of the process, press the Bulletin icon/button (fourth button) on the NovaManage Main Window. The following window will appear.



Process The purpose of this window is to view the status of a workflow. This window will display the status of only the workflow(s) started by the current user. Except for the "Stamp..." button, this is a default NovaSoft window. Therefore it will not be discussed at its basic form.

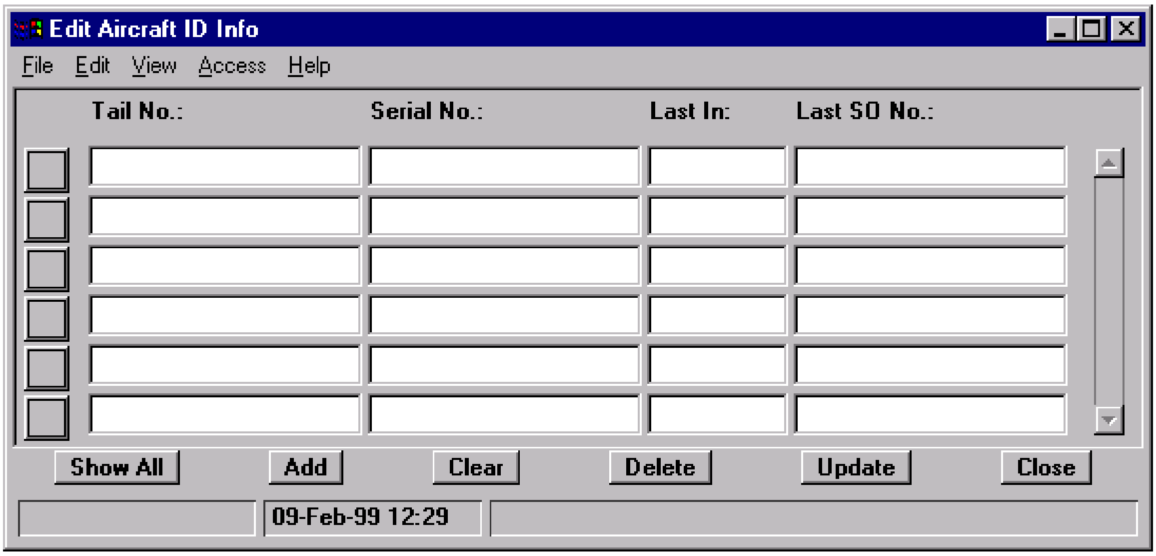
Modal/Modeless Modeless. The window can be closed or opened without effecting other windows.

Parent/Child Parent - Main Window
Child - Stamp (Password)
Read Note Window (Email messages)
Details window (Status details)

Procedure/Notes At each point in the approval process, the stamp button will be used. This button causes a window to appear asking for a the password of the current user. When the password is entered, the step is complete.

Window 9.0.0 – Edit Aircraft ID

The last button on the Lockheed Main Window is for tools / info purposes. The Aircraft info window allows you to enter or view aircraft information. The Service order window allows you to view service orders that have completed the workflow process.



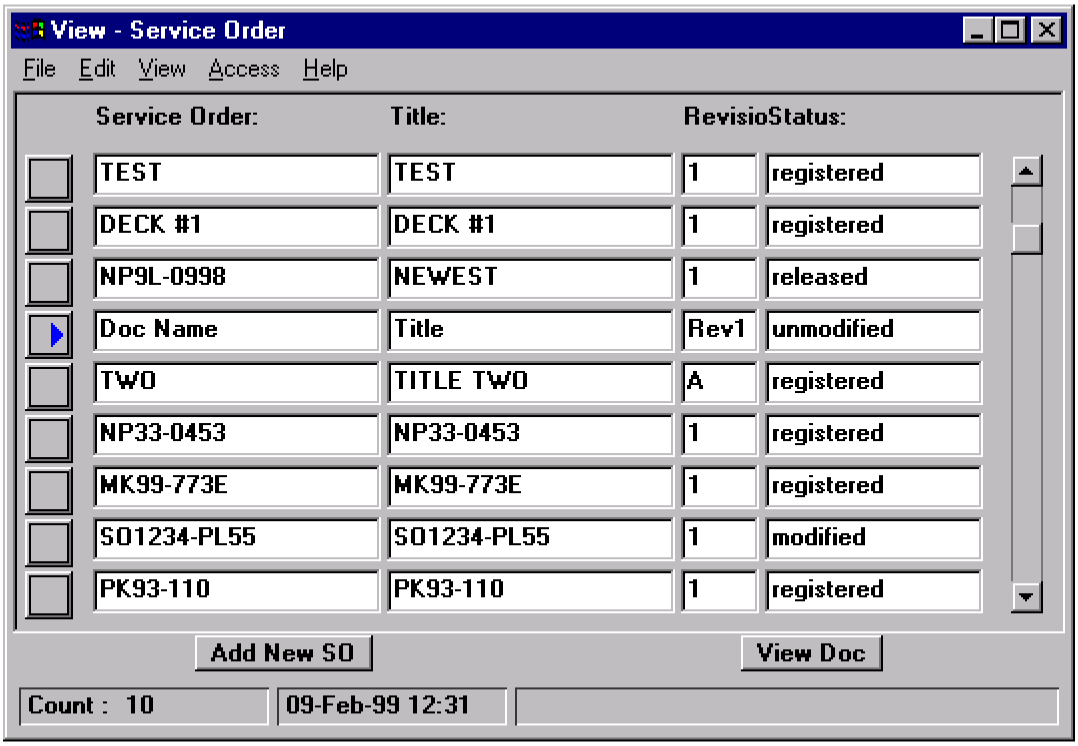
Process The purpose of this window is to enter the aircraft information. This information is used for audit purposes or any paper-trail references.

Modal/Modeless Modeless. The window can be closed or opened without effecting other windows.

Parent/Child Parent - Lockheed Main Window
Child - N/A

Procedure/Notes Select the "Show All" button to list all of the aircraft and their information. Select the box on the left to select a record for deletion or for editing. Type information into one field (any field) and press <Enter> to view the missing information of the chosen aircraft.

Window 10.0.0 - View Service Order



Process **The purpose of this window is to view past service orders.**

Modal/Modeless **Modeless. The window can be closed or opened without effecting other windows.**

Parent/Child **Parent - Lockheed Main Window**
Child - Service Order Open Registration
Logical Document Editor

Procedure/Notes **Press the "Add New SO" button to access the Service Order Open Registration window (Window 5.0.0). Select a Service order by pressing the button to the left of the record. Press the "View Doc" button to access the Logical Document Editor (Window 6.0.0) with the contents of the selected service order.**

APPENDIX G

WORK INSTR. NO. 5106	**DESCRIPTION – NOSE RADOME INSTALL**		**A/C S/N**	**AREA** **4-1**
OPERATION: SDLM – C9B	REVISION NO. 02	REVISION DATE 7-Jan-00	S.O. NUMBER	
PLANNER REVIEW	QA REVIEW	CUST. REVIEW		

INSTRUCTIONS:	INSTALL NOSE RADOME. REF: NAVAIR 01-C9B-2-53; CHP. 53-50-1. REMOVE ON W.I. 1027.
<u>NOTE</u>: (1)	**WORK INSTRUCTIONS ARE WRITTEN TO ENSURE COMPLIANCE WITH THE STATEMENT OF WORK. IF ANY CONFLIC BETWEEN THIS WORK INSTRUCTION AND THE AIRCRAFT CONFIGURATION, PLANNING MUST BE NOTIFIED IMMEDIATEL**
<u>NOTE</u>: (2)	**REVIEW ALL MAINTENANCE DISCREPANCY REPORT FORMS PERTINENT TO EACH AIRCRAFT BEFORE PROCEEDING. ALL INSTALLATIONS AND SERVICING REQUIREMENTS ARE COMPLETED, IF APPLICABLE, BEFORE PERFORM FOLLOWING.**
<u>NOTE</u>: (3)	**CLOSE ATTENTION WILL BE PAID TO ALL WARNINGS, CAUTIONS AND NOTES.**

CARD #	ITEM #	DESCRIPTION	MECH	Q.C.
	1.	**OK** TO INSTALL NOSE RADOME.		
		<u>INSTALL NOSE RADOME</u>.		
	2.	SUPPORT RADOME IN OPEN POSITION. **<u>CAUTION</u>**: NOSE RADOME WEIGHTS APPROXIMATELY 55 POUNDS AND REQUIRES A MINIMUM OF TWO MEN FOR SUPPORT DURING REMOVAL/INSTALLATION.	M	

	3.	INSTALL RADOME HINGE BOLTS.	M	
	4.	CONNECT HOLD-OPEN STRUTS TO RADOME.	M	
	5.	LOWER RADOME (FIG: FIG. 201) AND SECURE WITH LATCHES.	M	
	6.	ADJUST LATCH PLATES AS NECESSARY TO ELIMINATE ALL MOVEMENT OF RADOME WHEN RADOME IS CLOSED AND LATCHES. **NOTE**: THE LATCH PLATES CAN BE ADJUSTED BY LOOSENING LATCH PATE ATTACH SCREWS, MOVING LATCH PLATES FORWARD OR AFT ON SERRATED MOUNTING, AND TIGHTENING LATCH PLATE ATTACH SCREWS.	M	

WORK INSTR. NO. 5106	DESCRIPTION – NOSE RADOME INSTALL		A/C S/N	AREA 4-1
OPERATION: SDLM – C9B	REVISION NO. 02	REVISION DATE 7-Jan-00		

	7.	REMOVE MINIMUM AMOUNT OF MATERIAL FROM AFT EDGE OF RADOME TO OBTAIN A CONSTANT GAP OF 0.065 TO 0.130 INCH BETWEEN RADOME AND FUSELAGE SKIN. **CAUTION**: DO NOT TRIM FUSELAGE SKIN. **NOTE**: THE AFT EDGE OF THE RADOME MUST BE FAIRED WITH THE FUSELAGE SKIN WITHIN 0.045 INCH OVER AT LEAST 90% OF THE RADOME/FUSELAGE SKIN JOINT. UP TO 10% OF THE CIRCUMFERENCE MAY HAVE A FAIRING DISPARITY UP TO.118 INCH.	M	I
	8.	VERIFY AREA IS FREE OF FOD AND ALL TOOLS ARE ACCOUNTED FOR.	M	
	9.	INSTALLATION OF NOSE RADOME COMPLETE AND OK.	M	I

WORK INSTR. NO. 5106	DESCRIPTION – NOSE RADOME INSTALL		A/C S/N	AREA 4-1
OPERATION:				

SDLM – C9B	REVISION NO. 02	REVISION DATE 7-Jan-00	
ILLUSTRATION			

CHAPTER 10
MAINTENANCE RESOURCE MANAGEMENT ON-LINE SEMINAR

Terrell N. Chandler Ph. D.
Galaxy Scientific Corporation

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

10.1 EXECUTIVE SUMMARY

Airlines, repair stations, manufacturers, and the Federal Aviation Administration (FAA) Flight Standards are all under pressure to train personnel to perform a broader range of tasks. Personnel are expected to be skilled in more areas, while fewer dollars are available to meet training needs. While on-the-job training is essential for efficient, effective and safe performance of aviation maintenance personnel, travel to training centers and time away from the job are not cost effective or efficient means of training personnel.

The Gore Commission (Final Report to President Clinton by the White House Commission on Aviation Safety and Security, (http://www.aviationcommission.dot.gov) encouraged the FAA to capitalize on advanced technology to improve aviation safety. In response, this research project offers distance education as an instructional approach where people engage in educational activities without having to be at the site where the instruction is occurring. The Safe Maintenance in Aviation Resource and Training (SMART) Center provides a forum for training and discussion of issues related to Maintenance Resource Management (MRM). This prototype is designed to investigate the utility and feasibility of web-based resources and training centers for the aviation community.

The first on-line MRM seminar was administered from January 4 through February 8, 1999. In this report the SMART Center and the MRM seminar are described. An extensive analysis of the seminar activities and participant evaluation is performed. The report closes with recommendations for future seminars of this kind and a look to future trends in the field of on-line training.

There is no question that the target audience, Aviation Maintenance Personnel, valued the training and saw the Internet as an appropriate vehicle for delivering training. Analysis of participant data revealed that the participants all had backgrounds in aviation maintenance, but within that field there was a wide range of expertise. The participants also represented many areas of the U.S., Canada, and other parts of the world. Participants were very active, not only working their way through the Computer Based Training (CBT) curriculum, but also reading many of the class materials and participating in the chat discussions. The technology stood up reasonably well to active use, though this is the area where the most improvements can be made. The goal in this area should continue to be to make the technology transparent to the user.

Given the target audience, working aviation maintenance personnel located worldwide, the seminar activities were designed to be primarily self paced and accessible any time, day or night. One of the reported drawbacks to distance learning, however, is the isolation students' feel when trying to learn remotely[1]. To minimize the feeling of isolation, we provided several means for interacting with staff, content facilitators, and other participants. Another design decision that was crucial to the success of the seminar was the conscious decision not to burden the participants with too much technology. Sophisticated technology (live video and audio) is often perceived as the optimal solution to distance education. However, one must moderate this tendency with the goal of the course work, the technical sophistication of the audience, the available hardware, and the available bandwidth. Often the coursework does not require sophisticated technology to meet its stated objectives. One must weight the cost of equipment support, software required, the learning curve and increase likelihood of technical failure to the value added in the medium used. For example, don't risk relying on a high-risk technology that many people don't have to support a core requirement of your course. The success of any on-line training will be do more to pedagogue than technology, though technology can enhance good pedagogy if implemented well.

10.2 BACKGROUND

10.2.1 Why Distance Education

MRM is a more challenging training effort than Crew Resource Management (CRM) because aviation maintenance involves larger more dissociated groups of personnel who must coordinate successfully with each other. Further, the daily individualized, non-proceduralized decision making is greater in maintenance than in flight operations.

Distance education is an instructional approach where people engage in educational activities without having to be at the site where the instruction is occurring. Instruction, resources, and students can be distributed across many different locations, and are usually connected together by technologies, such as computer networks, satellite dishes, and telephone lines. One approach to distance education is to capitalize on the technical capabilities of the World Wide Web (WWW) to create resource and training centers for continuing education of professionals. The SMART Center (Safe Maintenance in Aviation Resource and Training) is an example of such an approach for the delivery of On-the-Job Training.

Web Based Training (WBT) and centralization of information resources lends itself not only to setting standards for MRM practice but also will serve the community as a forum for discussing issues unique to MRM and providing a central repository for MRM research and training resources. The interactive nature of the web both in terms of live interaction, asymmetric interaction, and the dynamic evolution of information over time is the most compelling reasons for research and development of a SMART Center for the aviation community.

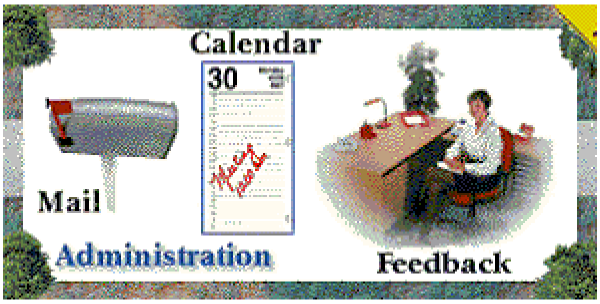
The main purpose of the research product is to promote safe operations in aviation maintenance through the application of human factors concepts and skills, in a distance education forum. The focus of the SMART Center is to train aviation maintenance personnel in MRM concepts and skills. MRM is the chosen topic because the subjects taught within the MRM curriculum (e.g., communication, teamwork, situation awareness, performance management) are applicable to all levels of the aviation maintenance community nationally and internationally.

10.2.2 A Description of the SMART Center

If an individual wants to participate in the MRM seminar, he or she first goes to Registration to sign up for the seminar. The participant chooses a user name and password. When she or he submits the registration request he or she is placed on the course mailing list. The security password provides access to registered class materials and activities.

After entering the SMART Center, seminar participants find themselves looking at a map of a virtual school. The map divides the school into four conceptual areas: Administration, Classes, Resources, and Recreation.

In the Administration area, the class mailing list allows participants and instructors to send mail to each other and to submit or receive assignments. The Calendar facility informs participants of current events relevant to the course. Feedback provides a vehicle for participants to give the [SMART] Center staff feedback on course activities and content.

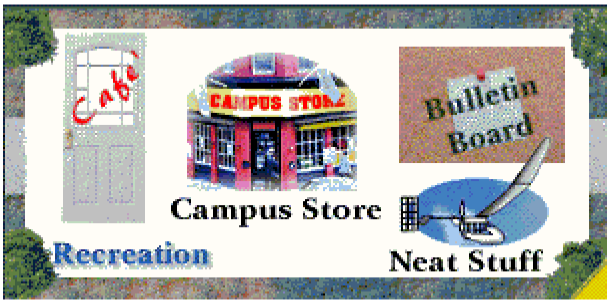


Interactive classes occur in the Lecture Hall, Lab, and Conference Room of the Classroom Area. Real-time lectures can be given through real audio-, video-, or text-based chat sessions. The type and sophistication of the equipment required for the class will change with the type of activity that is planned for the class. Text-based conference sessions require no additional equipment while real-time audio or video sessions require additional equipment and protocols. Transcripts from the conference chat sessions are posted in the Conference Summaries area. The Computer Based Training (CBT) Lab is where the core course materials are presented. Tests for each unit are also found within the CBT Lab.

The Resource area is where general resources pertinent to the seminar are found. Participants can view or download reading materials found in the Class Materials area. They can view on-demand lectures or demonstrations in the Audio/Video area and they have access to references, relevant to human factors in aviation maintenance in the reference area.

For the [MRM] course, a video lecture found in the audio/video area introduces the seminar participants and the basic conceptual themes of each of the course sections. The CBT Lab provides interactive multimedia presentations and activities. Testing also occurs in the CBT Lab area. Participants can quiz themselves on the central concepts of each section through a multiple-choice test. Through several facilities (e.g., Calendar and Email) students are informed of dates and times when instructors will be available to discuss a particular course section. These textual chat sessions are held in the conference facility and are based on the readings found in the class materials area. When the participant has mastered all the sections in the course, a certificate of completion is sent to a designated address.

The Recreational area is where more informal interactions may occur. The Cafe is a meeting place for interest groups to gather and chat. Announcements for new classes and other community activities can be posted on bulletin boards. The Campus Store is where participants can update their browser and download any plug-ins they may need for the course. New applications that might be of interest to the group are found in the Neat Stuff area.



10.3 RESEARCH OBJECTIVES

The research tasks for the SMART Center project are as follows:

- Design and implement a resource and training site for aviation maintenance personnel,
- Develop a course that teaches Maintenance Resource Management,
- Conduct the MRM seminar, and
- Evaluate the merits of the project based on the following criterion:
  - Who participates? How many participate? In what manner do they participate?
  - Do they complete the course work?
  - How well does the technology stand up to the demands of active use?
  - Is the delivery of the seminar cost effective?
  - Does the target audience value the training?
  - Is the Internet accepted by the course participants as an appropriate mode of delivery?
  - How well are the site and course materials designed for the target audience?
  - Is this form of training cost effective?

10.4 METHODOLOGY

This research followed a modified Instructional Systems Design approach. The steps that were taken are:

- Analyze current on-the-job training needs for aviation community.
- Design and development of SMART Center and MRM course.
- Employ recognized experts in the field of human factors in aviation maintenance and inspection to write MRM course content and participate as experts in on-line MRM seminar.
- Conduct quality assurance test of all software that will support SMART Center and MRM course curriculum.
- Evaluate seminar on the following criterion:
    - participation
    - course completion
    - technology robustness
    - cost effectiveness
    - value added
    - overall design

10.5 PILOT STUDY

McDonnell Douglas/ Boeing volunteered to used the MRM web-based training in a pilot study to demonstrate the potential for web-based training in an open lab for on-the-job training of aviation maintenance technicians (AMTs). The original intent was to show a proof of concept to the industry and then create a consortium of airline and 3rd party maintenance companies who would share the cost for future online training courses. McDonnell Douglas/Boeing had originally planned to train 200 AMTs using the online MRM CBT portion of the SMART Center during the summer of 1998. Unfortunately, the training department was dismantled not long after the pilot study started. Thus only the first group of students were able to complete the training. Even with this smaller group of 20 students, the pilot study gave the research team valuable feedback about the on-line training experience prior to the seminar start in January 1999.

The training was conducted over a local intranet located in a room setup as a computer lab. The trainees were given an orientation session to cover the basic operation of the computer and an introduction to the MRM CBT Lab. They were instructed to work through the eight units of the CBT Lab during their down time. If they reached 100% criterion on all eight quizzes in the Lab, then they would receive a certificate of completion for the course from McDonnell Douglas/Boeing. The Lab was open, with a proctor, during most working hours.

Of the 20 who started the first training course, 9 finished. The 11 who did not finished had been sent to another location midway through training period and were unable to complete the training. Verbal reports from the instructor were enthusiastic. He reported that he had never seen such a serious, concentrated, effort from his AMT trainees. He also assured the researchers that it was not from lack of interest that the 11 students did not complete the course, but from location changes beyond their control.

Table 10.1 Evaluation Form Submitted by 20 McDonnell Douglas/Boeing AMTs

Ease of Use	7.5
Intuitive	8.2
Navigation	7.6

Response Time	7.9
Like Display	8.9
Amount Learning	8.3
Ease Testing	5.2
Concepts understandable	9.1
Relevance	9.4

Table 10.1 shows a summary of evaluation form questions filled out by the 20 students. The evaluation form can be found in Appendix A. The scores are based on a 10 point scale: 1 = low and 10 = high. Trainees found that they liked the display even though they did not always find it easy to use or navigate. They thought the information to be understandable and very relevant to their job. They reported learning a fair amount but they found the test questions difficult.

Figure 10.1 shows the average number of tries it took all the students to reach 100% criterion for each quiz. There seemed to be a psychology of 'test taking' at play. For most tests, students achieved 100% in one to four tries, but often there was one test where an individual would experience a mental block. Sometimes it would take 10 to 15 tries to reach 100% for that particular test. Many people took longer to get 100% on the first test, which we assume is due to learning how to take the quiz. Some students had trouble with other quizzes but there was no pattern of one test being more difficult than another test. We will compare these test scores to the January seminar participants' performance on these same tests later in the report.

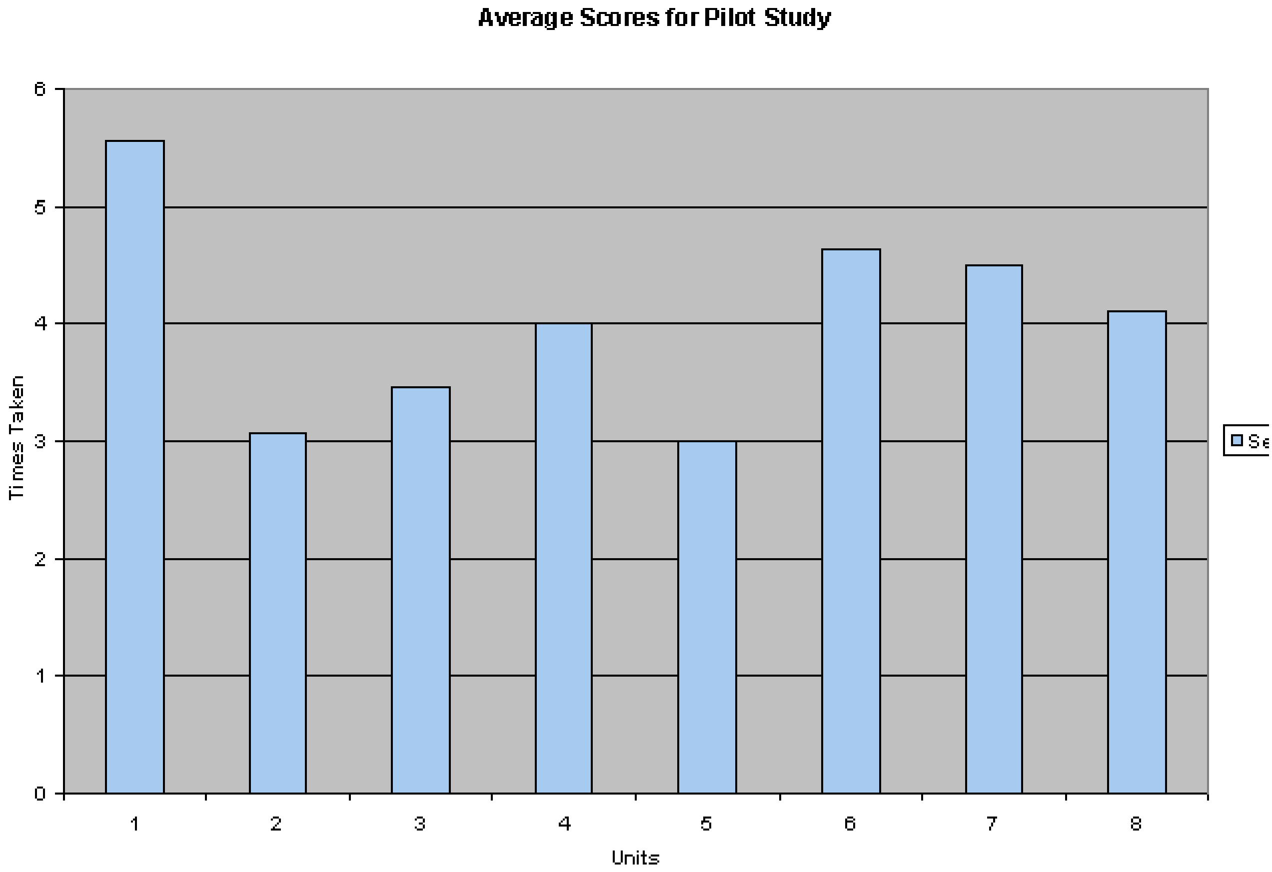


Figure 10.1 Average Scores for Pilot Study

The pilot study gave the research team important quality assurance feedback for both the core curriculum and the training application that was to be used in the January seminar. From this initial experience we found that the core curriculum was appropriate to our primary audience, the AMT, and the delivery system was sound. In other words, the application was stable, the multimedia played across an Intranet in reasonable time, and the interface was relatively self explanatory and easy to navigate.

10.6 THE JANUARY SEMINAR

10.6.1 Technical Features

Since the research team knew that we were going to be catering to an audience that could span the world, we tried to match what was technically required of the student with enough power to present an interesting and motivating seminar. Table 10.2 lists the hardware and software requirements for the students. We made every effort to limit the number of applications that the student needed to install. The student was expected to have equipment that could handle graphics, connection to the Internet, and a browser that could handle Active X and Java applications. Internet Explorer was the recommended browser, though Netscape Navigator, AOL and CompuServe were also supported. Audio and video were used to enhance the course, but the medium was not essential to successfully participate in the course.

Table 10.2 Hardware/Software Requirements for Students over Internet

Hardware

- Computer with 8 Mgs of Ram (16 recommended)
- 28.8 Modem or Network PC card
- Sound Card (optional but recommended)
- Internet Service Provider

Software

- Browser: Internet Explorer 4.x, Netscape 3.5 or newer, AOL or Compuserve 4.x, Internet Explorer (recommended).
- Audio/Video use Vivoplayer.

We used a hybrid system, Sun Unix and Microsoft NT, for our servers. We took advantage of the robust security, volume, and history tracing capabilities of the Sun Unix system, while also taking advantage of the database, Microsoft Active Server Pages, and Active X capabilities offered by the NT Server. This gave us the most flexibility to offer a wide range of application features. Table 10.3 shows each feature of the SMART Center and the language in which the feature was.

Table 10.3 Language Used for Each Feature of the SMART Center

Administration

- Registration of all participants (Unix, Perl)
- History trace of participant activities (Unix, Perl)
- Mail
  - Email list of participants, facilitators, staff - used by staff. (resident email)
  - HTML listing email addresses of all participants and facilitators - used by participants. (HTML, resident email)
- Feedback Form (Unix, Perl)
- Calendar (CGI)

Class Activities

- Conference Chat Room (Java)
- Conference Summaries (HTML)
- CBT Lab with HTML, streaming audio, streaming video, testing and student tracking (NT, Active Server Pages)
- Lecture Hall with live video, live audio, text chat, white board - not used for current course (CUSeeMe + Reflector)

Resources

- Reference library with Human Factors Guide Book, all meetings proceedings, and reports for FAA/AAM Human Factors in Aviation Maintenance and Inspection for past 10 year plus 21 NTSB

Accident Reports. Full text search capability. (NT, Site Director)

- Audio/Video Library (Vivo, HTML)
- Class Materials (HTML, Site Director, WinWord, RTF)

Recreation

- Bulletin Board (Unix, Perl code, HTML)
- Campus Store (install programs for Internet Explorer, Netscape, Vivo player, PowerPoint player)
- Neat Stuff (Active X and Java)
- Café Chat Room (Java)

About (HTML, PowerPoint)

10.6.2 Description of Seminar Activities

The MRM seminar opened for registration during November and December. Registration closed in mid-December when the number of registrants exceeded the 50 person ceiling. Technically the SMART Center could easily accommodate 200 simultaneous users. The seminar staff felt that, for the initial class, it was better to service a smaller number of participants to insure each participant would receive the quality training he expected.

The seminar spanned roughly six weeks during January through February. The first week was orientation, followed by five weeks of the seminar proper. Participants were told they had until the end of February to finish the course work to receive their certificates of completion.

When the participants registered they were sent the seminar syllabus and a document stating what was expected of them during the course. In order to complete the seminar, they were expected to complete all eight units in the CBT Lab with 100% criterion on each unit test. They were also expected to sign up for four chat sessions, one orientation chat session, and three topic chat sessions. Prior to attending each of their chat sessions they were expected to read an article on the topic of discussion. Finally the participants were asked to fill out an evaluation form before the close of the seminar.

To see what the seminar would be like, the seminar staff had provided a demo version of the SMART Center that participants could walk through. The demonstration version of the SMART Center gave participants an opportunity to introduce themselves to each SMART Center feature and to learn how to navigate through the Center prior to the start of the seminar. Participants were instructed to visit the demo version of the SMART Center, download the audio/video plug-in, and install an updated browser if necessary. They were encouraged to visit each area of the campus map and read the description of the activity that would occur in that area. In the MRM CBT Lab, for example, instructions for using the CBT program were provided. In the Class Materials area, a list of the reading materials was provided along with instructions for using the text browser, Site Director. A video of each seminar facilitator was provided in the audio/video area to introduce participants to the facilitators.

During December, participants were sent a series of “Hints for Success”, instructing them on how to best prepare for the seminar. This series of instructions covered such things as hardware and software requirements, computer setup, chat session scheduling, instructions for the MRM CBT Lab and the Chat Room, and video and audio requirements. Technical glitches that we knew about (such as Netscape playing some but not all of the video) was incorporated into these initial notes to the participants. Also, during December participants were asked to sign up for one orientation chat session and three topic chat sessions. Of the 53 initial registrants, 36 signed up for chat sessions. We took this to be an indication of the core group of participants.

The first week of the seminar was orientation week. Participants were expected to log in, orient themselves to the SMART Center if they had not already done so, view the introductory video for each unit, start the first two units of the seminar, and attend their practice chat sessions. The practice chat sessions was designed to orient students to text chatting, and provide them with an opportunity to ask the seminar coordinator questions regarding hardware and software requirements, the SMART Center, or the seminar. This first week is when all the unknowns about the technology were discovered and solved. These will be discussed in detail during the Evaluation section.

The seminar was designed to cover two units per week. Each week participants read the assigned articles and worked their way through two units of the MRM CBT Lab. On Mondays and Thursdays of the following week chat sessions discussed material covered the prior week and answered questions on that material.

Given the target audience, working aviation maintenance personnel located worldwide, the seminar activities were designed to be primarily self paced and accessible any time, day or night. One of the reported drawbacks to distance learning, however, is the isolation students' feel when trying to learn remotely. To minimize the feeling of isolation, we provided several means for interacting with staff, content facilitators, and other participants. The email address of all facilitators and participants were made available in the email area. A general list was not provided to everyone to prevent mass mailing abuses. The email of the staff was sprinkled throughout the Center for easy access. A bulletin board was set up for each unit topic for general discussion of the topic by all participants. And the chat sessions were set up to encourage live interaction between participants and facilitators. Summaries of all the chat sessions were then posted for everyone to read.

In general, seminar staff and participants used email primarily to work through technical difficulties or to answer subject matter questions. The staff made an effort to answer participant questions within the same day. The phone was occasionally used when helping a participant troubleshoot a technical problem; however, the phone was generally not necessary. Chat sessions were used, by participants and facilitators, as a forum for discussion about MRM. As the seminar progressed facilitators began receiving email from some participants wanting to discuss seminar content in more detail.

The seminar staff worked through technical difficulties and answered questions the first two weeks of the seminar. The remaining four weeks showed significant decline in the need for help. Most participants by then were actively working their way through the course.

10.7 RESULTS/DISCUSSION

10.7.1 Participant and Activity Statistics

Participant and activity statistics are summarized in Table 10.4. Of the 53 initial registrants, 36 people signed up for the chat sessions. This we considered the core group. Thirty participants completed all eight quizzes, which entitled them to a certificate of completion. Eight participants formally dropped out, seven cited schedule changes and one cited insufficient computing power. All of these people requested to be kept on the mailing list so that they might participate in future courses. One participant's email bounced back to us. Three participants were identified as guests who dropped in to visit but did not intend to attend the seminar fully. This left eleven participants who registered for the seminar, but neither participated in the chat sessions, nor completed any of the unit quizzes, nor contacted us in anyway.

Table 10.4 Level Of Participation	
Participants registered	53
Participants signed up for chat sessions (core group)	36
Participants completing course	30
Participants who formally dropped out, visitors or could not be reached	12
Unaccounted for registered participants	11
Participants participating in chat sessions	25
Participants unable to participate in chat sessions who completed course	5

Of the 36 core participants 25 participated in at least one topic chat. Many participants initially experienced problems with company firewalls. Most participants were able to resolve these technical barriers within the first orientation week of the seminar. Three participants could not resolve the firewall problem prior to the seminar's end, preventing them from attending the chat sessions. It is unknown why two of the participates finished the lab tests but did not participate in the chat sessions. We suspect that they, too, experienced firewall problems or another technical problem they could not resolve.

The participants represented a large demographic cross-section. All the participants worked in aviation maintenance, however, the capacities varied greatly. Table 10.5 shows the cross-section of core participants in terms of their occupation. Managers were the largest group of participants followed by Technical support engineers and AMTs.

Table 10.5 Occupation of Participant with in the Aviation Maintenance Field

Manager	8
AMT	5
Technical Support Engineer	5
Supervisor	4
Human Factors Specialist	4
Trainer	3
Quality Control	3
Safety Officer	2
Military	1

Vice President Company	1

Table 10.6 shows the home states and countries of the participants. As you can see there is almost a one to one correspondence between number of people participating in the seminar and locations from where they were signing-in. Georgia is the location from which the seminar was broadcast and from where most of the facilitators signed in.

Table 10.6 Location of Participants

Location	Participants and Facilitators
Alabama	1
Arizona	2
Arkansas	1
California	2
Columbia, South America	1
Florida	3
Georgia	6
Germany	1
Indiana	1
Malaysia	1
Massachusetts	1
Mauritius, Africa	1
Mexico	1
Missouri	1
Nevada	1
New Hampshire	1
Norway	1
Ohio	2
Ontario, Canada	4
Pennsylvania	3

Somerset, UK	1
Texas	2
Vancouver, Canada	2
Washington (State)	2

10.7.2 Email Correspondence

The primary mode of communication between staff, facilitators, and participants throughout the seminar has been email correspondence. Table 10.7 shows categories of the typical correspondence from participants, Table 10.8 shows typical problems that were encountered and the solutions that were offered, and Table 10.9 is a list of constructive criticisms about the technical features of the course.

Table 10.7: Typical Discussion Topics through Email
• Inquires about seminar • Questions about registrations • Questions about the target audience • Questions about technical requirements • Inquires of what should be expected technically • Notifications (or expressions of frustration) when things didn't work • Good to go notices when things are working • Changes in location during seminar • Expressions of great interest in seminar material • Concern about missing orientation, chat sessions • Responsible for payment? Cost? • Closing before deadline, wanting to register colleagues after registration closed • Regular reports on progress made - both technical and content • Notice – completed CBT in 7 working days • Statistics and other info sent to us by participants • Request for guest visitors • Asked if could access info from two locations • Want to create an MRM email site for continuing the connections started • When will MRM manual and CD to be sent out?

- How can we continue this momentum
- Did you get my feedback form?
- Is the NT server faster, seems that way.

It is interesting to follow the evolution of each individuals email correspondence. From inquiry to questions about registration, through the trails of setup, orientation, and technical troubleshooting, to the glee exclaimed when they are "good-to-go!" then notes of progress through the content and connections through the chat sessions, and that final sense of satisfaction when the seminar is completed.

Table 10.8 Problems and Solutions

Logging on
• Wrong URL
    • Sent URL
• Can't remember password or name
    • Sent name and password
• Some registrations didn't take
    • Checked all registration names and passwords, re-entered ones that didn't take
• Problems with capitals
    • Reminded them about case sensitivity

Can't open attachment (most people had no trouble with this) • Sent as MS Word 6 file instead of rich text format (rtf) • Sent information to different email address • Embedded information directly into email message
Orientation confusion • "Hints for Success" email • Individual email responses • Phone calls (rare)

Chat schedule
• Embedded table lost format
    • Resent chat schedule without table format
    • Sent chat schedule as attached word document
    • For those who could not read attached files sent their schedule individually (few)

- Schedule changes prevented participant from attending chats they selected
    - Told to go to whatever chat sessions they could
    - Added more evening chats to accommodate people working at home

Office firewall problems can't reach chat
- Administrators opened up port 7000 (many)
- Participant setup at home instead of office
- Some did not participate in chat portion (a couple)
- Schedule more orientation chats for those who missed because of setup problems
Other chat problems
- Browser version (script error message)
    - Upgraded browser
- Text wrap around error
- Duplicate names error
    - Fixed errors - wrap around, duplicate names
- Browser connection times out
- Sometimes freezes up with no explanation don't know if internet overload or client problem
- Transfer interrupt
    - Need to clear cache, user had hit stop during transfer

Video problems
- Netscape did not play MRM CBT video
    - Recompile CBT video in future to upgrade with browser
- Aloha aircraft video end without completion
    - Could not verify problem

Download timed out   - Need to set browser to longer timeout
Sun Unix System went belly-up on 2/9/99   - Able to move most files to NT within day. Most areas functional within two days

Most technical and scheduling problems could easily be handled through email. Even firewall problems were handled primarily through email announcements. The curricular plan we had in place for the seminar was not so rigid that we could not assist individuals. Our biggest change was to add more chat sessions to accommodate those who missed practice sessions due to technical difficulties. Evening chats were also added to serve people working from home.

Table 10.9 Constructive Criticism

- CBT test questions that need to be reviewed
  - Leadership #5
  - Airline Safety – "1970 accidents increase, decrease, stay the same" - answer in is graphics which are hard to interpret.
  - "An incomplete maintenance log is an example of " - trick question.
  - "Where do teams collapse?" - confusing question.
  - Unit #3 "Human Factors began during WWII not after."
  - Unit #4 CTD risk factor on test not covered in Lab.
- Spell out acronyms
- Lab
  - Clicking on each topic title cumbersome (add page turning buttons)
  - Outline and toobars cut off text displays (put outline/toolbars on right and left instead of top and bottom; make toolbar smaller)
  - Human Errors in Maintenance. "Top eight common errors" - lists only seven.
  - Human Factors Fundamentals - same video shows up for both definition of human factors and description of system.
- Couldn't print lab material (will send CD-ROM with lab material)

Constructive criticism cited during the seminar was minor content and interface issues that were easily corrected. Once people became comfortable with the SMART Center, they were content with how the Center operated. Correspondence dropped precipitously after the first two weeks of the course.

Email is an excellent way to coordinate adult learning. One can respond promptly to requests. The response can be individualized and thorough while simultaneously being quick and to the point. Students are appreciative of the attention they are given; they are polite, interested, informed, and ready to share.

10.7.3 MRM CBT Lab

Figures 10.1 and 10.2 show that both the AMTs in the pilot study and the January seminar participants performed similarly on the eight-unit tests. The pattern of testing was also similar. The seminar participants represent a much broader group and, in the field of human factors, probably a more knowledgeable group than the AMTs in the pilot study. For both groups, it took more trials to finish the first test then subsequent tests. There were participants in each group who struggled with individual tests, but there was no pattern of one test being significantly more difficult than the others. Quiz five seemed to be an easier quiz for both groups. From their responses in the course evaluation, there was a wide range in perceived difficulty of the tests even though there was not a large variation in how many trials it took for individuals to complete each test.

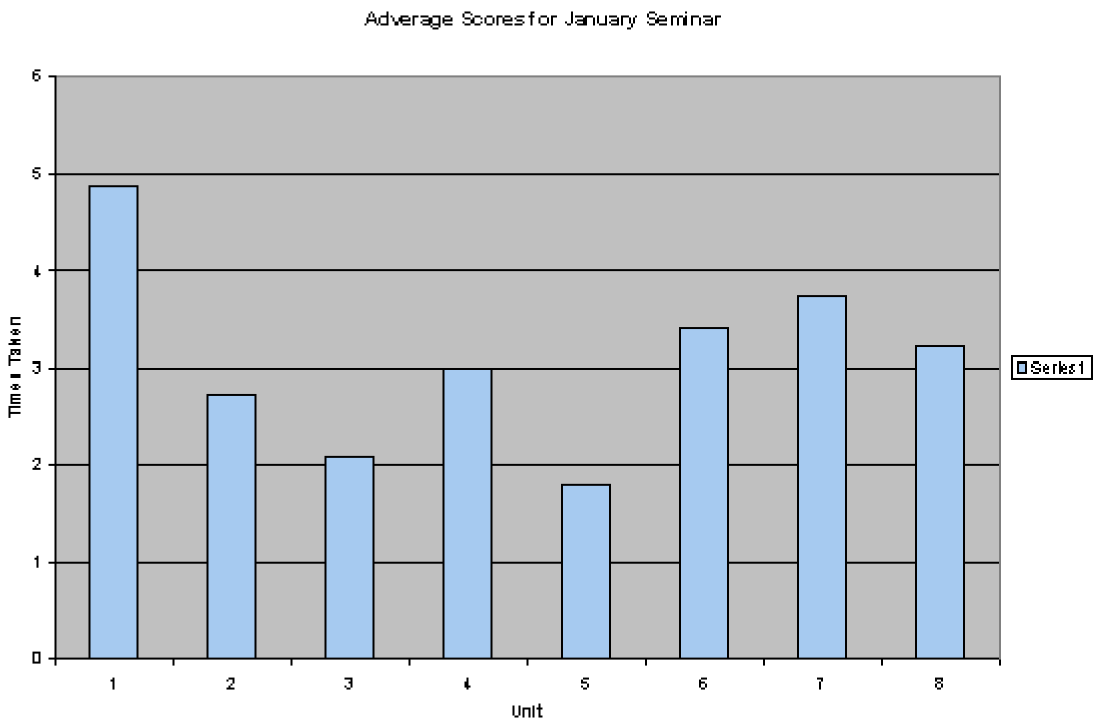


Figure 10.2 Average Scores for January Seminar

10.7.4 Evaluation Forms

Appendix B shows the evaluation form for Seminar participants. It is very similar to the form used by the pilot study. A few questions were added to glean more information about the participants and their motivations for attending the seminar. Some questions were added to include all of the SMART Center and not just the MRM CBT Lab. Unfortunately during the last week of the seminar the Sun Unix system, that served well for five years, died. We were able to move the SMART Center to the NT server; however, everything programmed in Perl could not run on the NT as it was currently configured. The evaluation form is one of those programs processed in Perl. We received 24 evaluation forms from the group that finished the course. About one third of those forms were faxed to us. We anticipate that had the feedback facility had been operating properly, we would have received closer to 30 evaluation forms. The complete compilation of the evaluation form can be found in Appendix C. Table 10.10 shows the numeric ratings for the nine major categories of questions.

The evaluation questionnaire covered two basic areas -- interface design and MRM content. Participants were generally pleased with the content. They thought the information very relevant and easy to understand. Some people thought the tests were difficult while others thought they were easy. Participants were more critical of the interface design but not overly critical. They found the directions sufficient to get them started, though some participants experienced disorientation when navigating through the site initially. Once students got their bearings they found the center well laid out and easy to use. The esthetics of the site were pleasant but not outstanding.

Appendix C shows the written responses for all the questions on the evaluation forms with the exception of the biographical information. The short answer questions are designed to elicit specific positive and negative aspects of the content and interface. The questions are in the form of “Did you every feel lost or disoriented? If so when and where?” or “Was there any information explained particularly well?” By eliciting specific examples of what participants liked or did not like about the experience, we are better able to improve the SMART Center and its content for future courses. Below are samples of participant responses to the short answer questions.

3c. Did you ever feel lost or disorientated? If so when and where?

"I felt disoriented at the beginning when I had some troubles with the first chat session and some programs installation. It was difficult for me to find out when It was a problem with my PC and when with the Web. It would be helpful to have a troubleshooting section on web."

?"At the beginning trying to navigate was tough being I had never used the net before. One plus that it was open prior to the beginning of the seminar allowing me to practice and find areas. The suggestions that were sent out on the usage also helped. The only thing was that I accidentally came across the reading material. I went back through the session information and did find it after the fact."

5b. If you were to change the displays, what would you add or delete?

?"I really hated the way the course material was broken into sections. It was a hassle to have to back and forth to get to the next section. It would have been nice if it was all in one scroll down area."

?"I liked the displays it made me feel like I was back in college a bit with the campus theme."

Table 10.10 Program Operation - Numeric Ratings

Person	1a. Ease	2a. Intui-tive	2b. Direc-tions Suffi-cient	3a. Easy Navi-gate	3b. Easy find Info	4a. Response Time	5a. Like Display	6a. Under-Stand Info	7a. Relevant	8a. Tests Difficult	9a. Learned
1		4	yes		10	8	10		7		
2	9	7	Yes	9	7	9	10	9	10	5	11
3	10	9	Yes	10	10	8	10	9	10	9	10
4	8	7	Yes	8	7	7	8	9	7	3	6
5	8	8	Yes	10	7	8	8	8	10	3	5
6	10	8	Yes	10	10	8	10	7	10	7	10
7	10	9	Yes	10	10	5	7	9	8	1	8
8	8	6	Yes	10	7	9	7	10	10	7	7
9	8	6	Yes	10	10	8	8	7	9	8	8
10	5	1	No	8	7	7	8	5	6	10	4
11	6	8	Yes	8	7	8	8	9	8	5	8
12	10	9	Yes	9	10	8	10	9	10	7	10
13	8	8	Yes	8	7	9	9	9	9	7	9
14	9	9	Yes	10	10	10	8	9	10	8	10
15	8	8	Yes	8	10	7	7	8	7	5	5
16	3	8	Yes	5	10	4	4	9	10	3	5
17		8	Yes	10	10	7	9	9	10	7	10
18	3	5	Yes	7	10	8	8	10	10	1	8
19	8	8	Yes	10	10	8	10	9	10	7	10
20		5	yes	3	5	7	7	10	10	8	9
21	6	6	Yes	8	10	9	9	10	10	3	10
22	9	9	Yes	10	10	8	9	9	10	2	10
23	5	7	Yes	9	10	5	10	8	10	5	10
24	7	6	Yes	7	7	5	1	9	10	9	5
AVG	7.5	7.0	17 yes 1 no	8.5	8.8	7.5	8.1	8.7	9.2	5.65	8.2

6b. Was there any information that you could not understand?

?“The last section performance management I found the hardest to get through. I don’t think it was because it was last but it seemed harder to read than the other sections. I found that PM was written to a higher level of understanding. I am not saying to remove it just make it easier to understand.”

6c. Was there anything that was explained particularly well?

? “Personally I thought the section on Human Error in Maintenance was well thought out. It had a lot of supporting information that a mechanic can see and relate to almost immediately. The one that in particular that stands out is the item titled A Hangar Example, and the cost break down, it is a great tool.”

7b. What information was particularly relevant or interesting to you?

?“The article on Group Communication was excellent! Because I live and breathe this stuff, most everything else was “old hat”. If the reading material was simplified or outlined in the CBT more it might be better received by the average AMT. Relevance to me or the AMT?”

?“The teamwork definitions explain exactly what I have seen in the business over the past 15 years! It's so true.”

7c. Did you find any information uninteresting or not relevant? If so, explain.

?“Some charts were boring. These charts did not have adequate indexes or reference marks.”

?“ERK and MESH - Unless you have a staff of 3 or more at a large airline, these are useless. You don’t have time. This would also bore the hell out of the AMTs! Even the simple to follow MEDA form evokes zzzzzzzzzz’s from the techs!”

?“not to down play that safety is a concern because it is. But, the section on worker safety was <not> the most interesting section in the program. It could be that do to all the classes I have had on worker safety it felt like one of those, “here we go again” type of things. Organizations that do not have actual safety programs may feel different about that section.”

8b. Were the test questions relevant to the content they were testing? Give an example of one that was relevant and one that was not relevant.

? “The Dirty Dozen was a good one to really cement into memory. Some of the Leadership questions were mindless.”

?“There appeared to always be one or two questions in the tests that may not have been directly addressed in the prerequisite readings. They were obviously placed to test the participants ability to understand the material as opposed to reading the material. I sheepishly admit to the fact it was these such questions that caused me the most difficulty. I would recommend the inclusion and perhaps more of these type of questions in future exams. I apologize for not having an example readily available.”

9b. List any ideas you learned about in this course that you think you could apply in your work environment.

?“Because I teach this course ALL of it applies. If I think back to when I was in the industry as a Director of Maintenance with 15 people working for me, once again I would say ALL. This has been a great awareness of what has been missing in the industry until now.”

?“Think situation awareness is a good thing to stress to people. With situation awareness in mind, many incidents should be stopped before they happens.”

?“Dirty Dozen info and communication within groups”

?“How to improve teamwork and cooperation. How to ensure information is passed on to ensure complete job is done.”

?“Situation awareness and communication”

?“There is not enough room to list everything. I believe nearly the entire course can be used, I believe a hard copy of the seminar is needed to reflect back to stimulate the memory also.”

10.7.5 General Comments

?“As my first experience in two topics: Maintenance Resource Management & Internet training, I felt great. I am really interested on get more information about MRM and now I get a commitment with myself: to share the information and learning's I get now. For all you folks that are in other side, congratulations for this very good job: MRM information, training structure and computers management, everything was great. And finally, to whom it may concern thanks for new technology.”

?“I was disappointed I could not use any of the videos. Some of the questions were a little backhanded, like question 5 in the last test. I did drop off during the chats a number of time???? I did not find the chats of much help. Other than the above, I found this a great way of getting the word out. I congratulate you, you may have saved a life today.”

?“Hope to see much more of this type of training in the future. An alternative to the chat sessions may want to be explored. Firewalls and time to participate seem to be barriers. Possibly a FAQ format would work better.”

?“Great info all the way round. CBT and chats worked very good. Thanks for the opportunity to join the group. Great Experience.”

Overall participants enjoyed themselves, they learned, they met new friends, they want their colleagues to take this course, and they want to do another course like this again.

10.8 LESSONS LEARNED

10.8.1 What We Did Right

It is apparent that despite some technical difficulties the seminar was a success. What were some of the factors that made this experience a success? Ironically the things we did right are primarily pedagogical. We limited registration to 50 participants, a manageable size. This size of the seminar allowed the staff to give each participant their undivided attention. Staff members made a point of responding to participants’ questions and requests within 24 hours. Staff went out of their way to accommodate schedule fluctuations and changes in (email) locations. The systems administrator worked closely with other systems administrators to solve firewall problems and other technical difficulties. Even if a participant became frustrated, he never felt ignored. This is very important public relations asset.

Roles of staff and facilitators were clearly defined. Each staff member knew what his or her responsibility was and had the authority to accomplish his or her tasks as needed. Facilitators had clearly defined responsibilities. They were expected to lead the discussion for the three chat sessions for the unit they represented. Usually the chat sessions were all on the same day. Facilitators were very good about covering each other if a scheduling or technical problem arose during a chat session.

Students were expected to read the materials assigned to the unit and come up with one or more questions or comments related to the material, which was then posted to the discussion bulletin boards or raised for discussion during the chat sessions. The facilitators also worked with the staff to create a introductory videotape of themselves, their background, and the unit they were to facilitate. The facilitators were given many practice chat sessions prior to the seminar's start so that they were comfortable with the technology and discussion format. This greatly helped their comfort level, which is another important consideration when implementing on-line interactive training. Instructors, facilitators, professors, and experts can not feel at a disadvantage with respect to their students.

Since most of the facilitators were volunteers and recognized experts in the field, an effort was made not to overburden each facilitator while also ensuring that what was requested of each added value to the seminar. There were a total of six facilitator for eight units. This gave the participants a range of expertise and points of view. This added more coordination on the part of the staff, but the added value was well worth the added work.

We did several things to facilitate orienting the participants. One was that we had a demonstration version of the SMART Center available to the participants during registration. This allowed the participants to familiarize themselves with the interface, download and test the browser and the video/audio plug in they were instructed to use. Also during registration the staff initiated correspondence with the participants to help prepare them for the upcoming seminar and set the tone for the new instructional experience. The first week of the seminar was orientation week where in addition to familiarizing themselves with the SMART Center they were given an opportunity to practice with the chat facility. These steps, though not fool proof, as noted in the "Where We Can Improve Section" did contribute significantly to the success of the seminar.

Another design decision that was crucial to the success of the seminar was the conscious decision not to burden the participants with too much technology. Sophisticated technology (live video and audio) is often perceived as the optimal solution to distance education. However, one must moderate this tendency with the goal of the course work, the technical sophistication of the audience, the available hardware, and the available bandwidth. Often the coursework does not require sophisticated technology to meet its stated objectives. One must weight the cost of equipment support, software required, the learning curve and increase likelihood of technical failure to the value added in the medium used. For example, don't risk relying on a high-risk technology that many people don't have access to support a core requirement of your course.

The staff chose a medium level of technology that provided multimedia and interaction to keep the seminar interesting, while minimizing the equipment and configuration necessary to participate in the seminar. Even so the technical requirement stretched the limits and patience of some participants. Only one person reported dropping out due to technical limitations. One does have to credit the ingenuity and sticktuative attitude of both the participants and the staff in tackling technical difficulties and the learning curve. It was the "we are all in this together" attitude that guaranteed the success of the seminar. The participants' positive attitude is a testament to this unique group. This does beg the question -- if on-line training is institutionalized and mandated will the success level go down? Undoubtedly that would be the case if one does not scaffold and streamline the technical learning curve, and if one does not commit to customer support of the training. Technical streamlining to the point of making the technology transparent to the user is essential if institutionalized, Web-base training is to be a reality. Customer service should not be compromised if training is to be a success.

The seminar had good ratio between independent work and interaction with facilitators. The seminar was setup so that a participant could complete the whole course and receive his or her certificate without attending one chat session. In the case of a few participants who could not access the chat sessions, this did not prevent them from participating. Posting the chat summaries encouraged these participants to keep up with the threads of the discussions and send email to facilitators to continue the discussion, which they did do. Chat sessions, email correspondence, and bulletin board postings were encouraged. Independent work provided participants with the ability to work anytime, anywhere at their own pace. Also the criterion for success was to master the material. It did not matter how long or how many tries it took. What mattered was that the material was mastered. This gave people a credible structure for achievement. One could feel good about success whether it took many tries or only a few to accomplish the criterion. Since we do not grade the participants on level of success, but rather we are raising the base knowledge of the group, this form of criterion for accomplishment works well.

10.8.2 What We Can Do Better

All the areas where the seminar can be improved are technical. There were several suggestions for improving the MRM CBT Lab. This included being able to print or download the content. Some participants did not like the outline structure of the interface, preferring continuous scrolling of the material or tabbing to the next and previous pages. For some reason Netscape Navigator would not play the video within the MRM CBT, though it would play the introductory video found in the audio/video area just fine. Some participants requested a larger viewing space for reading the content. Finally a few test items and content areas were flagged as needing revision. All of these technical and content improvements are easily addressed.

While design issues were noted for the MRM CBT Lab, upgrades were not performed during the seminar. Since the chat sessions were interactive, and problems usually effected that interactivity, several upgrades were made to the chat facility during the seminar. These changes were transparent to the end user. What one would note is that over the course of the seminar, fewer problems would surface.

There were several surprises that we did not anticipate. The most significant was the firewall problem. Because of the necessary network security for aviation companies, most of the participant who were taking the seminar while at work could not access the chat sessions due to blocks from corporate firewalls. Fortunately, most of the system administrators worked diligently with our web administrator to correct the problem.

Setting people up was not fool proof. There is the issue of how much do you tell people. If you tell them too much, people reach information overload and they stop listening. Also no matter how explicit you think you are, misinterpretation is common. Like any class, the level of expertise with respect to technical knowledge and comfort varied and, since we were using the internet, there was no standardization in equipment used. Despite the concerted efforts to keep the setup and orientation simple, in some circumstances it was not. Fortunately the diligence of both the staff and the participants overcame most of the setup problems encountered.

10.9 SUMMARY

When reviewing the initial research questions on the merits of the project we found that the participants all had a background in aviation maintenance, but within that field there was a wide range of expertise. The participants also represented many areas of the U.S., Canada, and other parts of the world. Of the 53 registrants, 57% or 30 participants finished. Of the core group of 36, who took the initiative to sign up for the chat sessions, 83% of that group finished. Participants were very active, not only working their way through the CBT curriculum, but also reading many of the class materials and participating in the chat discussions. The technology stood up reasonably well to active use, though this is the area where the most improvements can be made. The goal in this area should continue to be to make the technology transparent to the user. Both the pilot study and the January seminar verified that the course material and site design was appropriate for the target audience, AMTs. The January seminar further revealed that the design accommodates a broad student body. There is no question that the target audience valued the training and saw the Internet as an appropriate vehicle for delivering training.

Was the training cost effective? To run this course for a six-week period costs approximately $15,000 – or about $300 per person for a class of 50. For the time and attention that each participant received, this seems to be a reasonable starting figure. Larger class sizes will reduce the cost per pupil ratio. A happy medium will need to be found between class size and cost effectiveness. This estimate is for conducting the course itself, it does not include the cost associated with building the SMART Center site or developing the course material. Using this type of delivery, the industry should be able to increase their training commitment to maintenance personnel while realizing significant savings through less travel costs and less time away from the job.

The main advantage Web-based centers have to offer over all previous mediums are:

- The ability to simultaneously coalesce distributed information into one body of information that in turn is accessed by a decentralized group.
- The ability for information to dynamically evolve.
- The ability for people to dynamically interact.

Many people will continue to prefer an instructor, but cost accounting will drive training toward self-paced independent remote learning. The good news is, through Web-based training, human-to-human interaction may actually increase rather than diminish. If done well, individuals may actually get more attention, not less. The success of any given training will be to do more to pedagogue than technology, though technology can enhance good pedagogy if implemented well.

10.10 FUTURE TRENDS IN WEB-BASED TECHNOLGY

The next horizon of Web-based development sees a jump in sophistication from relatively simple HTML pages that many people can develop to sophisticated client side and client/server interactions hosted by a suite of new language standards and their supporting application tools. The new standards include HTML 4.0, Cascading Style Sheets (CSS), a document object model, ECMA Script (its predecessor is Java script) and XML. These new standards will usher in the new phase in web development - Dynamic HTML.

HTML 4.0 sets the stage for dynamic HTML by

- separating semantics from formatting,
- standardizing embedded scripting languages,
- broadening the scope of the HTML tag set itself and
- internationalizing the standards to accommodate different character sets and languages.

HTML 4.0 standard has also lead browser development in the arena of alternative devices accommodating users who can not see a monitor or use a keyboard 2.

Cascading style sheets are the mechanisms that allow one to separate content from format. Web document developers can define styles in a separate file that can apply to a series of documents rather than to a single document. Through unique tag definitions, CSS sets the stage for supporting different representations of material, depending on the context of the display. Styles cascade from general to specific. At the most general are rules that determine a whole class of documents. An example would be the general look and feel of a book. Document level styles are defined in the header of the file and determine unique attributes of a single document. A specific chapter may have rules for unique styles for that chapter. At the lowest level are in line styles most familiar to HTML developers that change a specific heading to a specific color or font, for instance. CSS1 is the current standard. The rules specified in CSS1 are not dynamic in and of themselves. Coupled with scripting language commands they enable the dynamic changing of a style rule after a page has been loaded. CSS2 will incorporate much more interactivity. One will be able to group Style elements and place them on their own levels independent of the content. That way, style elements can be turned on or off or repositioned depending on the current context3.

For a script to communicate with an object, it must know where the object is in relation to other objects. A window, a frame, a form and form elements are all scriptable objects. The document object model creates an internal hierarchical road map of all the scriptable objects. The W3C has charged one of its working groups with establishing a standard for HTML Document Object Model. This task has been one of the most challenging because the leading browsers, Netscape Navigator and Internet Explorer, handle objects very differently. Similarly Netscape and Internet Explorer have competing philosophies for how the document object model should be specified.

Client side scripting languages such as JavaScript and Vbscript are the languages that manipulate the document objects. These language scripts are embedded and run on the client side enabling unique responsive interactions with the end user. ECMA Script is an international standard that has been adopted recently to head off incompatibilities between scripts supported by different browsers. The ECMA standard is essentially JavaScript found in Netscape 3.0 and has been adopted by both Netscape 4.0 and Internet Explorer 4.0.

SGML is a specification mark up language that allows documents to describe their own grammar. HTML applications hard wire a small set of tags in conformance with a single SGML specification. XML is a specification language derived from SGML, but designed specifically for the web, that increases the level of sophistication in content presentation and interaction by providing publishers with a means to define their own markup language using application-specific meanings[4]. According to Bosak[4], "XML differs from HTML in three major respects:

1. Information providers can define new tag and attribute names at will.
2. Document structures can be nested to any level of complexity.
3. Any XML document can contain an optional description of its grammar for use by applications that need to perform structural validation." (p.2)

The areas where XML will be most useful are predicted to be:

- where the web client is expected to mediate between two or more heterogeneous databases,
- where the processing load is shifted from the server to the client,
- where different views of the same data is required, and
- where intelligent agents tailor information discovery to different users[4].

Intelligent agents are a set of new programming techniques that combine resent developments in object-oriented programming, artificial intelligence and artificial life research. What distinguishes intelligent agents from object oriented programming techniques are:

- agents are mobile independent objects,
- they are able to "learn" (that is, able to change their own rule base in the face of a changing environment) and
- they are able to interact and negotiate with other agents.

Some agents will interact directly with the user and as such will have "personalities"; others will work behind the scenes to gather and manage information. There are several challenging research areas that must be addressed in the next few years before intelligent agents become prevalent. Because being mobile and independent is a criterion for being an agent, agent technology requires languages that provide a run time environment independent of the platform that it is on. Java is a language designed for just such platform independence; however, true platform independence is still a major issue[5]. In the commercial Internet arena, interaction and negotiation with other agents demand a standard interaction language between agents. Security for both host servers and agents is another big research area[5]. Intelligent agents could extend the notion of the "personal coach" in training. They could keep track of user preferences, learning styles, and common mistakes performed by the user. One challenge is to be helpful and informative without becoming obnoxious. How to detect when a person is stumped and open to aid, verses actively troubleshooting and not interested in aid, is a tricky question. Research in comprehending user interactions and incremental learning by agents is another important research area.

While the strength and flexibility of the new standards promise to revolutionize (once again) the way information is processed and hopefully turned into knowledge, there are several substantial barriers to their immediate adoption. The browser industry is struggling to keep up with the new standards. And since different browser releases have come at different times during the standards development cycle, different releases support different aspects of the standards and sometimes use different language tags. To write for both browsers one must duplicate coding efforts or choose to leave out capabilities that are found in one browser but not another. The rule of thumb is to code for the common denominator between the two main browsers -- Internet Explorer and Netscape Navigator. To make matters worse users generally do not keep up with the latest browser versions. At work, many institutions and companies have standardized on browsers that do not support Dynamic HTML standards. In addition not all browsers react the same way on different operating systems. Internet Explorer 4.0 is particularly guilty of this incompatibility. Internet Explorer 4.0 is designed for Win32 operating systems and does not react as well on Win16 or Macintosh platforms.

These incompatibilities are currently seen as temporary barriers to an information and commerce delivery medium, which hold great promise. If the corporate powers can overcome their natural warlord mentality, then a truly new way of doing business will emerge. International standards and platform independent programming languages are steps in the right direction.

Dynamic HTML, distributed applications, and intelligent agent technology are the next level of sophistication in web development. These technologies promise to make web applications very dynamic. Soon one will not be able to appreciably tell the difference between CD-ROM based presentations and Web-based presentations.

10.11 ACKNOWLEDGMENTS

The author would first like to thank the FAA/AAM Program Manager, Jean Watson, without whom this project would not have been possible. The author would like to acknowledge Craig Earon and Charlena Kunkler for their superb work as members of the SMART Center staff. The seminar would not have been the success that it was without their talent and commitment to the project. I would also like to thank the seminar facilitators -- Bill Johnson, Ben Sian, Gordon Dupont, Dick Saboda, Dave Kraus, and Ray Goldsby -- for their expertise and dedication to aviation maintenance human factors. This group represents team work at its finest.

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10.13 APPENDIX A
Evaluation of Maintenance Resource Management Web-Based Training (MRM-WBT)

<u>Questions About the Program</u> Initials ________

This questionnaire is intended to give the designers of the MRM Web-Based training information about how well the program performed for you.

I. Program Operation

1. Ease of Use

1a. Please circle the number on the dimensional scale below that indicates how easy you found MRM-WBT to use.
Difficult <=====================+============================> Easy
1 2 3 4 5 6 7 8 9 10

2. Intuitiveness

2a. How intuitive is the interface?
Confusing <=====================+============================> Intuitive
1 2 3 4 5 6 7 8 9 10

2b. Were the directions sufficient to get you started?

2c. Did you access help? Once inside help could you find the information you needed?

3. Navigation

3a. How easy was it to navigate through MRM-WBT?
Difficult <=====================+============================> Easy
1 2 3 4 5 6 7 8 9 10

3b. Could you easily get to the unit you wanted from the table of contents?

3c. Did you ever feel lost or disoriented? If so when and where?

4. Response Time

4a. How was the response time overall?
Slow <=====================+============================> Fast
1 2 3 4 5 6 7 8 9 10

4b. How was the response time for going through each item in the concept outline? How about the video? How about the audio?

II. Screen Design

5. Display

5a. How did you like the MRM-WBT displays?
Dislike <====================+===========================> Like
1 2 3 4 5 6 7 8 9 10

5b. If you were to change the displays, what would you add or delete?

5c. Was the media quality adequate for the lesson?

III. Content

6. Conceptual

6a. How easily could you understand the information presented to you?
Difficult <====================+===========================> Easy
1 2 3 4 5 6 7 8 9 10

6b. Was there any information that you could not understand?

6c. Was there anything that was explained particularly well?

7. Information Relevance

7a. Did you find the information in MRM-WBT relevant to learning about human factors in aviation maintenance?
Not Relevant <====================+===========================> Relevant
1 2 3 4 5 6 7 8 9 10

7b. Did you find any information that was particularly relevant or interesting to you?

7c. Did you find any information that was not relevant or uninteresting?

8. Testing

8 a. How difficult were the test questions?
Easy <====================+===========================> Difficult
1 2 3 4 5 6 7 8 9 10

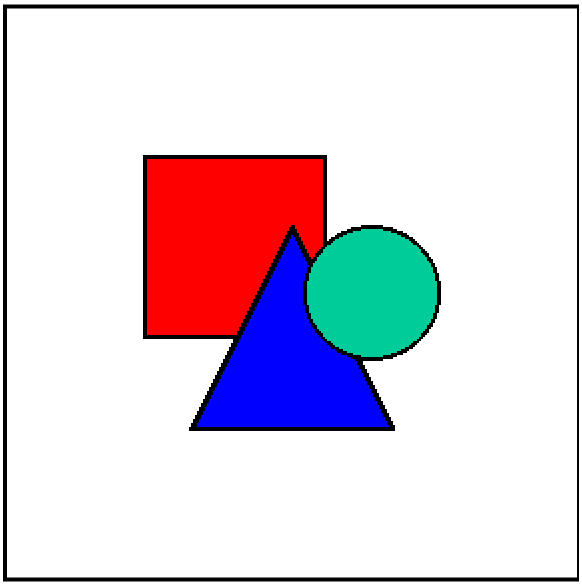
8b. Were the test questions relevant to the content they were testing? Give an example of one that was relevant and one that was not relevant (if any).

9. Learning

9a. How much do you feel you learned from using MRM-WBT?
Not Much <====================+===========================> A Lot
1 2 3 4 5 6 7 8 9 10

9b. List any ideas you learned about in this course that you think you could apply in your work environment.

10.14 APPENDIX B
Evaluation of Maintenance Resource Management Seminar (MRM-WBT)



Name or initials (optional):

Email address (optional):

Participant Information

P1. Please give us a brief BIO about your background and where you are from.

P2. Please tell us your purpose for taking this class.

P3. Are you primarily interested in MRM Content?

P4. Do you intend to finish the course and receive a certificate? Yes

Questions About the Program

This questionnaire is intended to give information about how well the program performed for you to the designers of the MRM Web-Based training.

I. Program Operation

1. Ease of Use

1a. Please enter a number between 1 (most difficult) and 10 (quite easy) to indicate how easy you found the SMART Center to use.

2. Intuitiveness

2a. Please enter a number between 1 (very confusing) and 10 (very intuitive) to indicate how intuitive you found the interface.

2b. Were the directions sufficient to get you started? Yes

3. Navigation

3a. How easy was it to navigate through the SMART Center (scale 1 = most difficult to 10 = quite easy)?

3b. Could you easily find the information or activity you wanted from the map? Always

3c. Did you ever feel lost or disoriented? If so, when and where?

4. Response Time

4a. How was the response time of the computer overall (scale 1 = slow to 10 = fast)?

II. Screen Designs

5. Display

5a. How did you like the SMART Center displays (scale 1 = dislike to 10 = like)?

5b. If you were to change the displays, what would you add or delete?

III. Content

6. Conceptual

6a. How easily could you understand the information presented to you (scale 1 = difficult to 10 = easy)?

6b. Was there any information that you could not understand?

6c. Was there anything that was explained particularly well?

7. Information Relevance

7a. Did you find the information in the MRM Seminar relevant to learning about human factors in aviation maintenance? (scale 1 = not relevant to 1 = relevant)?

7b. What information was particularly relevant or interesting to you?

7c. Did you find any information uninteresting or not relevant? If so, explain.

8. Testing

8a. How difficult were the test questions in the MRM lab? (scale 1 = easy to 10 = difficult)?

8b. Were the test questions relevant to the content they were testing? Give an example of one that was relevant and one that was not relevant (if any).

9. Learning

9a. How much do you feel you learned from attending the MRM Seminar? (scale 1 = not much to 10 = a lot)

9b. List any ideas you learned about in this course that you think you could apply in your work environment.

Comments:

10.15 APPENDIX C
Evaluation Form - Written Responses

3c. Did You ever feel lost or disorientated? If so when and where?

Participant	Comment
1	no
2	no I can always hit the BACK button
3	I felt disoriented at the beginning when I had some troubles with the first chat session and some programs installation. It was difficult for me to find out when It was a problem with my PC and when with the Web. It would be helpful to have a troubleshooting section on web.
4	Only with trying to get the Smartchat interface to work, and solving the Video problem.
6	no
7	No

8	I never did have any luck getting the videos to work.
10	In the beginning. Too much information, computer interfaces and setup were difficult to ascertain. No consistency with nomenclature e.g., ("Units" vs. the CBT sections).
11	trying to get into chats from behind corporate firewall
12	NO
13	Occasionally disoriented when in the class materials module. Not always sure of the section I was in. Chat center was confusing when it would not work. It basically returned message chat not available when actual problem was with firewalls.
14	Under Teamwork: On the Team Development page at the top, the last choice was "Storming: Part II". I was not aware I was supposed to scroll down for more topics until I took the test and found questions on "Norming" which were not previously covered. I went back to review and found I that I could scroll down at the top for more titles under Team Development. I subsequently passed the next test!
15	No problems. Just needed a little time to get used to the setup, but no problems.
16	no
17	never
18	At the beginning trying to navigate was tough being I had never used the net before. One plus that it was open prior to the beginning of the seminar allowing me to practice and find areas. The suggestions that were sent out on the usage also helped. The only thing was that I accidentally came across the reading material. I went back through the session information and did find it after the fact.
19	Only in getting started.
20	**Yes, when looking through the other resources. They would leave the MRM site, without notice. This then required starting over at log-in.**
21	**In the beginning of the course, I had some confusion as to where the chat sessions were to be held. Once I figured out where it was, the navigation became much easier.**
22	**no**
23	**never**
24	**no**

5b. If you were to change the displays, what would you add or delete?

Participant	**Comment**
3	displays were ok for me

5	I'm no web page designer, looked good
6	delete the golf
12	MORE VIDEOS, MORE LECTURE MATERIAL (AND MORE EASY TO DOWNLOAD)
14	At the top, it should have a down-arrow to indicate more choices below and to scroll down.
15	I would have made the lab without all the black border. On my browser at the job (Netscape 3.x) I could not get rid of the black borders. Therefore I also had to scan the page up and down. It should be easier to print or copy the lessons more easily than possible with this lab. Pages. Will you make them available in a printed form? The letters could have been a number or two bigger.
16	I really hated the way the course material was broken into sections. It was a hassle to have to back and forth to get to the next section. It would have been nice if it was all in one scroll down area.
18	I liked the displays it made me feel like I was back in college a bit with the campus theme.
20	Perhaps a little simpler so they would load faster.
21	Haven't given it much thought. I think what you had worked just fine.
22	I would add the photos of the facilitators and their Bio in a sub-menu of the Smart Center.
23	I thought they were very convenient.
24	Look more like TV or computer game.

6b. Was there any information that you could not understand?

Participant	Comment
1	When doing a course the reference material had to be downloaded. Scanning off of a screen when your browsing is most difficult. In labs, MRM references seemed to be only snippets AND NOT REALLY USEFUL. I felt that a HTL to specific chapters or manuals from the "library" would have … (cut off)
2	The last section performance management I found the hardest to get through. I don't think it was because it was last but it seemed harder to read than the other sections. I found that PM was written to a higher level of understanding. I am not saying to remove it just make it easier to understand.
3	Yes but it was about English language, I think (I speak Spanish) but once I got familiar with the new terminology it was OK.
5	I had to read some articles over but then it came together. No, all OK
8	NO
11	no
12	NO

13	No
14	Not so far.
15	No
16	The statistics stuff in the first section was a little confusing.
17	no
18	The only thing that I had a little trouble with was in the airline safety section. It was the chart under Total Accident Rate (plateau). The chart gives the annual rates on the left but only says from 1960-present it does not show the years on the graph.
19	No
21	no
22	Too much statistics in "Airline Safety"
23	Some information regarding performance management was a little hard to understand.
24	yes

6c. Was there anything that was explained particularly well?

Participant	Comment
1	The chat room information and directions seemed straight fwd.
2	first seven sections excellent
3	Yes, specially when there were statistics and no aviation examples. About examples I mean those that were used about the daily life. Human behavior on job: awareness, teamwork, communications.
4	The practical examples - particularly the piece on the Canadian military
5	The whole thing. I really like this training concept.
6	There was so much information available if required, there was really no excuse not to have an understanding of the subject material.
8	Leadership styles, communication
10	Not until I stumbled around for days!
11	some questions had what I thought were more than one
12	COMMUNICATION AND MRM CHAPTERS
15	Situation Awareness
16	I liked the section on human error.
17	Chat summaries were very helpful
18	Personally I thought the section on Human Error in Maintenance was well thought out. It had a lot of supporting information that a mechanic can see and relate to almost immediately. The one that in particular that stands out is the item titled A Hangar Example, and the cost break down, it is a great tool.

19	Everything was well done. Critical examination would get in the way of my search for content.
20	Added resource material really added to the basic lesson plan.
21	I enjoyed situation awareness and communications the most.
22	Team building and situation awareness
23	Risk reduction was very well explained.
24	some

7b. What information was particularly relevant or interesting to you?

Participant	Comment
1	1 - Some info was too basic. I suppose it would depend on your backgrd. If you had any previous background it would be very slow.
2	2 - every section
3	3 - Accident vs. maintenance human error statistics.
4	4 - Human behavior on job: awareness, teamwork, and communications.
5	5 - Worker Safety.
6	6 - Performance management was one particular area that I found very interesting.
8	8 - All
9	9 - The part Communication and Situation awareness.
10	10 - The article on Group Communication was excellent! Because I live and breathe this stuff, most everything else was “old hat”. If the reading material was simplified or outlined in the CBT more it might be better received by the average AMT. Relevance to me or the AMT?
12	12 - IN FACT, ALL OF THE INFORMATION WAS REALLY IMPORTANT
13	13 - Dirty Dozen, Communications.
14	14 - The teamwork definitions explain exactly what I have seen in the business over the past 15 years! It's so true.
16	16 - human error, situation awareness and communication.
17	17 - Gordon Dupont's The Dirty Dozen errors in maintenance
18	18 - As stated above the section on Human error in maintenance: A few of the areas in that section that are relevant and eye opening is the Heinrich ratio, the top seven causes of in flight shutdowns and the mental limits disassembly.

19	At this point everything is interesting and relevant.
21	See 6c
22	Communication
23	Communication
24	Stats of safety

7c. Did you find any information uninteresting or not relevant? If so, explain.

Participant	**Comment**
1	Some charts were boring. These charts did not have adequate indexes or reference marks.
2	it was all interesting and relevant.
4	Some of the Communication and Leadership info was a bit repetitive
7	Human factors fundamentals, Team work, Situation awareness, and Human error in maintenance.
8	NO
10	ERK and MESH - Unless you have a staff of 3 or more at a large airline, these are useless. You don't have time. This would also bore the hell out of the AMTs! Even the simple to follow MEDA form evokes zzzzzzzzzz's from the techs!
12	NO
14	Not yet.
16	no
17	none
18	not to down play that safety is a concern because it is. But, the section on worker safety was the most interesting section in the program. It could be that do to all the classes I have had on worker safety it felt like one of those, "here we go again" type of things. Organizations that do not have actual safety programs may feel different about that section.
20	no
22	no
23	I thought they were all relevant. I also liked the fact that sme questions application of those concepts learned.
24	no

8b. Were the test questions relevant to the content they were testing? Give an example of one that was relevant and one that was not relevant.

	Comment

Participant	
1	One question that did not seem to be relevant was how had aviation safety changed (better or worse) since 1970. The references were too vague and could have been simplified.
2	There were some question that I took 3 or 4 cracks at to get the right answer and example PM question 8. I think all four answers were correct. question 5 in PM" is not a barrier" maybe could have been worded so it was not a double neg. The questions in the PM section seemed to be different from the other sections
3	all questions were relevant to me
4	The Dirty Dozen was a good one to really cement into memory. Some of the Leadership questions were mindless
6	There appeared to always be one or two questions in the tests that may not have been directly addressed in the prerequisite readings. They were obviously placed to test the participants ability to understand the material as opposed to reading the material. I sheepishly admit to the fact it was these such questions that caused me the most difficulty. I would recommend the inclusion and perhaps more of these type of questions in future exams. I apologize for not having an example readily available.
7	yes
10	I thought that the CBT testing format was cumbersome and frustrating. Some of the questions were too "twisty" and would stymie the average AMT (and slow engineer!). The average AMT needs more "tools" not "theory." "If this, then this" kind of stuff. This was a good primer for Safety/HF practitioners, but it needs some more relevance to the "common man." In question 8a. It was not that the questions were hard but confusing. Maybe the word "difficult" should be defined or substituted. The answers on the test should be numbered or "lettered". Getting out and going back into the test was cumbersome. Too many key strokes. You had to get out of the test go back to any section then hit test then go back into the test, answer all the questions again (if you remembered them , just to answer one that you skipped. If you got another wrong by mistake, you had to repeat the whole process again! By this time most would have given up. Or been driven to say nasty things to the computer! AsI said before, AMTs hate to be tricked, made a fool of, or frustrated! I think there was little time to let the information "sink" in. Specific numbers are irrelevant e.g., $350 million means nothing. Its a big number! That's it.
12	YES. ALL OF THE TESTS WERE REALLY A FEEDBACK TO ME AND THEY WORKED AS A VERY IMPORTANT WAY TO IMPROVE IN MY BLIND SPOTS DURING MY MRM LEARNING.
13	Yes
16	yes
17	Very relevant
18	The question that was confusing until I really though about it was during the Performance management test question 5) Which of the following is not a barrier to leadership. Laziness was the answer. It was confusing because it was not actually mentioned verbatim in the text it was more of a common sense answer. A relevant question of a great reminder was in the communication test question #1) In the communication process, the form of communication: includes spoken, written or visual. It seems that people forget that he is use all 3 items can and does make the best impact.
20	yes
24	Aleady sent to Terry

9b. List any ideas you learned about in this course that you think you could apply in your work environment.

Participant	Comment
1	I would like to see this application used to host a site that would be accessed by safety counselors in the field. They would be asked to respond to a battery of test questions periodically. The test results would be evaluated immediately and both the individual and the … (cut off).
2	Because I teach this course ALL of it applies. If I think back to when I was in the industry as a Director of Maintenance with 15 people working for me, once again I would say ALL. This has been a great awareness of what has been missing in the industry until now.
3	How maintenance personnel could not be aware of his job consequences on time an place. Look for comply with strict safety requirements in order to avoid accidents, nor just to comply with the authority paperwork. Training is basic but could be really a cost or expense (administration looking) if it is not well focused and prepared.
4	A lot of the Teamwork stuff has application in our environment.
6	I am confident that I can effectively apply all of the sections throughout different duties of my responsibility.
9	Personal performance, right communication, right leading.
10	I am developing a course on group communication skills based on the information in the Communication within Groups article. We have excellent “Office” leadership skills courses here but the AMT Managers and Supervisors do not find the office environment relevant to their hangars. We also need a Technical Leadership course for them. In my spare time!
11	distance learning methodology, setup, procedures
12	COMMUNICATION, PROBLEM SOLVING, SHIFT AND WORK DESIGN, ETC.
13	Just about everything. It gave me several ideas for training in MRM. Will also serve as a valuable information resource for developing the training.
15	Think situation awareness is a good thing to stress to people. With situation awareness in mind, many incidents should be stopped before they happens.
16	It was a good course. I already knew a lot of it, but did learn some more. I can apply communication section.
17	Dirty Dozen info and communication within groups
18	There is not enough room to list everything. I believe nearly the entire course can be used, I believe a hard copy of the seminar is needed to reflect back to stimulate the memory also.
20	How to improve teamwork and cooperation. How to ensure information is passed on to ensure complete job is done.
21	Situation awareness and communication
22	To stress the importance of Human Factors in Aviation Maintenance.
23	Risk reduction, communication, leadership.

General Comments

	Comment

Participant	
1	The problem of portal access within the FAA is a big problem. I never was able to visit the chat room at any time. My Lan administrator felt uncomfortable about the issue. My idea about using this type of program to obtain info that is needed in the filed has many applications. Remote testing or learning has wide application both by the FAA and by air … (cut off).
2	I have found the course to be excellent but as everyone probably says that the very very best way is to be in a classroom with other humans. The chat sessions are very good for long distance training. Please, Please, Please, do not stop the program here. The word is getting out there and I have a lot of contacts now that want your training. If the funds were there maybe even a MRM II where MRM trainers can work with other trainers or for people in the Aircraft Manufacturing industry. In Canada the Canadian Aviation Maintenance Council is also working on DISTANCE LEARNING of HF. If you need a contact name just let me know. I am just afraid that for the companies that are not pro-active, that they will not send there people to a class room . They will say “Here is a CD on human factors, do it at lunch, or at home on your time not mine. We are too busy to do that on company time” But this would be extremely helpful as a recurrent training course to be taken yearly after the classroom course. An E-Mail site for all of us to continue to COMMUNICATE with each other and others interested in Aviation Maintenance and Manufacturing Human Factors. I know that the CRMers have this and it is very successful. For everyone that worked on this, keep up the work and please DON’T stop what has been started here.
3	As my first experience in two topics: Maintenance Resource Management & Internet training, I fell great. I am really interested on get more information about MRM and now I get a commitment with myself: to share the information and learning's I get now. For all you folks that are in other side, congratulations for this very good job: MRM information, training structure and computers management, everything was great. And finally, to whom it may concern thanks for new technology.
4	Make the course material easier to print out - much would be good to have for refresher review at a later date.
5	I was disappointed I could not use any of the videos. Some of the questions were a little backhanded, like question 5 in the last test. I did drop off during the chats a number of time???? I did not find the chats of much help. Other than the above, I found this a great way of getting the word out. I congratulate you, you may have saved a life today.
6	Keep up the terrific work. All the facilitators and Terry Chandler are very knowledgeable and accommodating. This is relatively new to most people and as technology advances, hopefully their (mine included) computers will be able to process and display the audio/video portions more

	effectively. I am very impressed with the efforts put forth by everyone at Galaxy Scientific and wish everyone involved continued success in this very commendable program. Please feel free to contact me at any time should there be any questions concerns, or you just want to say hi.
8	Being involved in designing a program and working with several university professors and many other experts in the field the last few years, most of this was a refresher course for me. I enjoyed the course very much. I believe communication (written especially)i.e. turnovers, non-routines log books continue to need attention. I believe situation awareness plays a large role in the errors that are committed. Another source is that not everyone reads the paperwork thoroughly. step by step. Thanks for the effort that was put in to this program. Look forward to another course.
11	great stuff !!!!
12	IT IS VERY IMPORTANT TO REPEAT THIS COURSE TO SCHEDULE MORE PEOPLE OF MY COMPANY, ESPECIALLY THE SHIFT SUPERVISORS, ENGINEERS AND INSPECTORS (IN THE NEXT COURSE) AND A&P MECHANICS (IN THE THIRD COURSE).
13	Hope to see much more of this type of training in the future. An alternative to the chat sessions may want to be explored. Firewalls and time to participate seem to be barriers. Possibly a FAQ format would work better.
14	This is a preliminary submission. I will submit again after 100% completion. So far so good!
15	I suppose the number used in tables are for USA only. Fine if number and lists etc. more clearly tells if they are for USA or the whole world or for certain airlines. Taken a little further, I think this is a fine way to learn, get ideas, and get in touch with people in the HF field. What about a contact area for different items, where one can put in questions and find answers, exchange ideas and tips. The videos could have been some better to observe, but that has something to do with my browser I guess. Will it be possible to get the video in a such form that they can be used in a class? Several of the videos could be fine to show in a class as samples.
17	Great info all the way round. CBT and chats worked very good. Thanks for the opportunity to join the group. Great Experience.
18	I personally had problems getting through my corporate firewalls to get into the chat sessions. Your technical people helped out a quite a bit with my computer dept. trying to get through but we found more firewalls than corporate was even aware of. I did follow the programs through the chat session notes and was able to ask a few questions of one of the presenters. In my opinion besides (continued) the chat session format I believe a tele-com session should be made available. This would help with the individuals who type slowly or are embarrassed by their spelling and also with individuals who are better at verbalizing their ideas and the use of emotion. I believe that GTE or AT&T could help with the initial set up. I know

	that United Airlines, Continental, and NWA use a similar system to communicate with all the amt (showed) places at one time. Thanks for the opportunity to be part of this event.
19	I have not had time to reflect specifically on the details of the course. Overall, it has been a positive experience and well worth the effort.
20	Overall concept is good. Actual lesson plan and testing were a bit basic. Would like to be able to down load other resources and basic lesson so they could be <read offline>. Never got video to work. Too bad.
21	I was happy I attended. I would be interested in taking other courses online as they become available. Thank you.
22	Looking forward to more of such Web Based Training. Thank you to all of you!!

CHAPTER 11
STUDY OF FATIGUE FACTORS AFFECTING HUMAN PERFORMANCE IN AVIATION MAINTENANCE

Ben Sian
Galaxy Scientific Corporation

Jean Watson
Office of Aviation Medicine
Federal Aviation Administration

11.1 EXECUTIVE SUMMARY

The reliable performance of aviation maintenance technicians (AMTs) is always of paramount importance to all stakeholders in aviation. These stakeholders include the general public, AMT employers and AMTs themselves. Fatigue has been identified as one factor that negatively affects performance. Likewise, several other factors interact and may lead to fatigue. Anecdotal evidence, and research in other areas, point to duty time assignments as one of these other factors.

This report details an exploratory study that examines AMTs' duty time assignments. Because this study is observational in nature, no prior hypotheses were made. The unit of observation and measurement was based on individual responses. Data were collected regarding number of hours worked daily and weekly, hours sleeping or in other activities, amount of experience, affiliation, and job type. Other relevant data were collected and available for future analysis.

The results portray a sample of people who work significantly more than the "typical" 40 hour work week. The structure of a respondent's typical duty time assignment points to eight hour daily shifts. However, most respondents indicated working at least six days per week, resulting in an average of 48.4 (σ = 9.2) hours worked per week.

In addition, most respondents did not obtain the recommended eight hours of sleep per night. Respondents averaged 6.7 (σ = 1.1) hours of sleep nightly. No data were recorded to examine reasons for this relative lack of sleep.

Finally, respondents completed a survey that measured their attitudes regarding their desire to work their current assignments. In general, respondents did not indicate the desire to work more or less hours than their current assignments. An examination of respondents' comments supports this. Taking into account their comments, respondents seem to value their work hours, but support a reconfiguration of their duty time assignments to allow for more stability and time off.

11.2 INTRODUCTION

The study of duty time assignments is a response to a petition to the Federal Aviation Administration (FAA) and recent National Transportation Safety Board (NTSB) recommendations regarding duty time limitations for maintenance personnel. For example, Tepas[1] stated that a review of duty times for maintenance personnel is highly sought after by the NTSB. Presently, few such regulations exist, especially when contrasted with the regulations currently on record for flight personnel (FAR PART 121.461-121.525 *Flight Crew and Air Dispatcher Personnel Duty Time Limitations and Qualifications*). This Federal Aviation Regulation (FAR) mandates the amount of rest flight personnel should receive before specific periods of flight time. For example, 10 consecutive hours of rest are required for flights lasting between 8 and 9 hours. Regulations have also been enacted for flight attendants, requiring 9 hours of scheduled rest for 14 hours of duty time in any 24-hour period.

The regulation that addresses duty time limitations for maintenance personnel is FAR PART 121.377, *Maintenance and Preventative Maintenance Duty Time Limitations*. The regulation follows in its entirety:

> Within the United States, each certificate holder (or person performing maintenance or preventative maintenance functions for it) shall relieve each person performing maintenance or preventative maintenance from duty for a period of at least 24 consecutive hours during any seven consecutive days, or the equivalent thereof within one calendar month.

According to some anecdotal evidence, the current duty time limitations are inadequate at best. Some aviation maintenance technicians point to fatigue as a causal factor for errors in judgment and that fatigue was often linked to extended duty times. As compelling as this evidence may be, however, it is not scientifically reasonable to rely solely on anecdotal evidence or case studies. In addition, it would be inappropriate to use current studies of fatigue in other situations (the most notable are those occurring on the flight deck) and generalize them to the hanger. As Tepas[1] states in his discussion of fatigue and aviation maintenance technicians (AMTs), what may be appropriate for the flight deck may not generalize to maintenance personnel. This may be due to differences in basic tasks, environmental/workplace differences, differences in informational processing demands and other environmental factors that affect feelings of fatigue. Several of these differences will be discussed in more detail in later sections.

It is possible that a generic regulation concerning duty times could have been created, but to do so in the absence of any significant data would be counterproductive. For example, a generic, wide-reaching regulation created without an initial assessment could have disparate impact among different facets of the maintenance community. Regulation of AMT duty times without the benefit of prior study could even have an unforeseen, negative impact. The variation among airlines, repair stations, and other facilities necessitates a more refined approach towards possible regulation that takes into account the needs, desires and the current situations of AMTs. To accomplish this goal, data are being gathered to determine the extent to which duty-times may or may not be hazardous.

The objective of this study is to gather baseline data specifically geared towards duty times in aviation maintenance. Establishing such baseline data is necessary to guide any further research in this area. These data will lay the foundation for additional studies that specifically investigate fatigue and performance decrements. Such metrics, however, remain outside the scope of the current study. Due to the exploratory nature of this study, no specific hypotheses have been made prior to data collection.

This report consists of three distinct sections. Section One reviews fatigue as an overall concept including, but not limited to fatigue as a factor in decrements in human performance as well as precipitates of fatigue. The section concludes with a discussion of the effects of fatigue.

Section Two discusses the survey instrument in more detail as well as the respondent pool used for the current study.

Finally, Section Three discusses the results of the survey as well as their implications. Future courses of study are also proposed and recommended.

11.3 FATIGUE

Everyone has experienced fatigue at one time or another. However, fatigue remains, scientifically, a somewhat nebulous construct. Fatigue, as a construct, can be viewed as both an independent and dependent variable.[2] Fatigue may exist as a pre-existing state, for example, that results in specific outcomes (independent variables), or it may be the result of a set of antecedent conditions (dependent variable). This wide variety of interpretations result in an equally varied number of studies of fatigue. Therefore, it is important to define fatigue specifically for this study and explicitly state the limitations of this definition.

This study discusses fatigue in terms of both outcome and antecedent. First, extended duty times are identified as a precipitate of fatigue.[3,4] Second, fatigue, in turn, is related to decrements in human performance and increases in human error.[5] Figure 11.1 illustrates this model of fatigue. The following sections will discuss these assumptions of fatigue in more detail. However, it must be understood that no direct metrics of fatigue were recorded for this study and that fatigue remains a largely implied construct.

11.3.1 Antecedents of Fatigue

This section examines fatigue as an "dependent variable," in which specific factors affect a person's level of fatigue. Several factors are discussed, among them sleep, shiftwork, circadian desynchronization, duty times, stress, and workplace design.

11.3.1.1 Sleep

Several researchers point to a loss of sleep as the primary cause for fatigue.[6,7,8] Sleep is a complex vital function that restores brain function.[9] A loss of sleep, for example, is significantly related to poorer performance in vigilance, memory, reaction time, coordination, decision making, and information processing among other cognitive skills.[7] A recent study has shown that 17 hours of sustained wakefulness resulted in performance decrements equivalent to a blood alcohol concentration (BAC) of .05. For comparison, most states currently define legal intoxication as .08 BAC. A .05 BAC is comparable to two 12 ounce beers.

Despite individual differences, most adults require an average of eight hours of sleep. It is estimated that no more than 5% of the population requires less sleep.[10] In addition, sleep loss accumulates should a person continue to lose sleep over time.[7] For example, if an individual who requires eight hours of sleep sleeps only six hours for four consecutive nights, the two hours of sleep loss would accumulate into eight hours of sleep debt. In other words, this person would require a full night's sleep in order to recover from sleep debt and become fully functional. Fortunately, the human body compensates for this sleep debt by obtaining deeper sleep over the course of one to two nights. This extension is less than would be normally required to "catch up." However, it is still necessary for one to sleep more than they have been in order to erase the sleep debt. Full recovery may in fact require two nights of uninterrupted sleep.[11]

Sleep loss also manifests itself in terms of "microsleeps," during which the body and brain attempt to compensate for a lack of sleep. Microsleeps are instances where sleep-deprived individuals lapse into a momentary light sleep, as is indicated by electroencephalogram (EEG) responses. In such instances, individuals are opaque to their surroundings and are incapable of processing relevant stimuli.

Finally, sleep also serves as a benchmark for assessing the impact of changing or manipulating a particular work schedule.[1] For example, gauging when and how much sleep a worker gets provides telling clues about differences between night and day shift workers. These differences include, but are not limited to, noticeable differences in performance on certain cognitive tasks. These differences were attributed to the interaction between lack of sleep and time of shift.

11.3.1.2 Shiftwork

Like sleep deprivation, shiftwork imposes unique burdens on an individual's physiology. Shifts commonly refer to a specific work period, as in the day or night shift, while shiftwork refers to changing work hours.[12] Physiologically, all living beings are regulated by an internal, biological clock. This clock is the source of the *circadian rhythms* that guide our every moment. These circadian rhythms manifest themselves through regular oscillations in basic bodily functions. These functions include body temperature, neurotransmitter output, blood pressure, heart rate, and cell division. Cognition is also tied into these functions in terms of decision-making, vigilance, and instances of depression.

Exposure to light is the primary stimulus for regulating the biological clock. This exposure to light "resets" the clock and synchronizes the appropriate somatic functions. In addition, these functions operate at their peak capacity during their light ("day") cycle. Therefore, the phenomenon of the 24-hour workday is contrary to the natural rhythms determined by evolution. Indeed, the increasing demands of modern day society require an increasing flexibility from those who supply the labor. As such, "non-standard" work periods are becoming increasingly common. A non-standard work period is defined as a period of work in which half the regular hours worked fall between 4:00 pm and 8:00 am. Twenty percent of all full-time employees fall into this category.13 Non-standard work schedules have been shown to have several deleterious effects, particularly for night shift employees.

Night shift employees, for example, are more susceptible to increased stress, high blood pressure, higher divorce rates, lowered job satisfaction, and depression among other disorders. Accidents and errors on the job are also more prevalent during the night shift. Akerstedt estimated that three-fourths of night shift employees report instances of sleepiness every night.14

It is possible for one to adapt to a night schedule. However, because of the stimuli that the body uses to reset the biological clock, this adaptation does not occur readily. Daylight is but one example of such stimuli, but increased opportunity for social interaction may interrupt one's ability to adapt to the night shift. In other words, a person sleeping during the day has more opportunities for interruption than a person sleeping at night. These are also the same reasons that it is much easier to adapt from night shift to day shift as opposed to the converse.

11.3.1.2.1 Circadian Desynchronization

Circadian desynchronization occurs when one's biological clock is in conflict with external stimuli.5 In other words, one may be required to work, for example, when his or her biological clock is indicating a period for rest. Therefore, the external stimulus (work) is not in sync with the individual's circadian rhythm.

Circadian desynchronization usually occurs when one travels through many time zones (i.e., jetlag.) Obviously, jetlag is a major concern for those who study flight deck performance. However, circadian desynchronization also occurs whenever shifts are rotated. In this way, rotating shifts directly impact the AMT. Shift rotation has differential effects, based on the direction ("forwards" or "backwards") and frequency of rotation. Fortunately, rotating shifts do not contribute to the majority of shift-related problems.11 Shifts in the aviation maintenance community are relatively stable, when compared to the frequency of rotation in other industries. However, because most flights occur in daylight hours, the night shift accounts for a large majority of the work.

11.3.1.3 Duty Times

The amount of time one spends on work is another a contributor to fatigue and decrements in performance. Though several other factors (type of work, energy expenditure, task type, etc.) affect the amount of fatigue generated on or by the job, it is common knowledge that one's performance eventually degrades if carried out continuously. The length of shifts varies from industry to industry. Though the current standard remains eight hours per day, other industries, such as nuclear power, have standard 12-hour shifts.15 This same study demonstrated that overtime is significantly related to decrements in safety performance, though a direct causal relationship was unclear.

In aviation, flight deck personnel are limited to no more than 34 hours of flight time in seven consecutive days and no more than eight consecutive hours of flight time for eight hours of rest per 24 hour period (FAR 135.265). Flight attendants are also assigned duty time limitation and rest time requirements, though they are somewhat less stringent.

The differences between the tasks performed by flight personnel and maintenance personnel make it difficult to generalize these regulations from one to another. Other factors, such as task type, posture, noise level, ambient temperature, and other environmental factors, have differential effects on personnel in terms of fatigue and error. For example, while Baker, Olson's study demonstrated that overtime was related to performance decrements for operations personnel, there is less evidence of this relationship for technical and maintenance personnel.15

11.3.1.4 Other Factors Leading to Fatigue

Several other factors, in addition to lack of sleep and time on duty, contribute to fatigue. The most significant are discussed in this section.

11.3.1.4.1 Stress

Stress is defined by the psychology literature in a number of ways. Stress can merely mean "arousal" and, when defined as such, may even promote performance in certain cases, as demonstrated by the Yerkes-Dodson curve. However, stress more commonly has negative connotations. Kushnir defines stress as a "diffuse and global negative experience accompanied by other negative emotions such as anxiety, frustration, dissatisfaction, and depression.16"

Stress is manifested by a series of symptoms that can lead to more significant health problems. Though fatigue is one of these symptoms, headaches, muscle tension, and increased cardiovascular distress are others. Stress may derive from problems related to one's personal life, but often, the job of the AMT contains stressors as well. In fact, Kushnir suggests that the occupational stress levels for aviation groundcrew are equal to and in some cases, exceed those in pilots.16

11.3.1.4.2 Information-Processing Demands

Finkleman investigated several contributors to job stress and their overall contribution to employee fatigue. The contributors were information-processing demands, job control, job effectiveness, pay rate, physical demands, job challenge, quality of supervision, as well as sleep deprivation.2 The respondents included almost 4000 temporary employees separated largely into clerical and light-industrial activities. Finkleman's findings show, perhaps surprisingly, that sleep deprivation had little impact on feelings of fatigue among workers. Instead, the factors that contributed most to perceptions of fatigue on the job were jobs with low information processing or physical demands (i.e., "boring"---jobs that lacked employee control, and low pay.)2

The results of this study may only have limited applicability to the AMT environment. Whereas sleep deprivation was not a major contributor to on-the-job fatigue, the majority of respondents worked an average of 33.5 hours a week, far less than the typical full-time employee. In addition, when factoring out clerical employees, sleep deprivation became more of a predictor of job fatigue. However, Finkleman's results indicate that other job stressors contribute significantly to job fatigue.2

11.3.1.4.3 Ergonomic Considerations

Physical factors located in the workplace also contribute to feelings of fatigue in employees. For example, an incorrectly designed workspace or station may contribute to a higher frequency of fatigue among employees. A badly designed workspace may require workers to repeat actions in an inefficient manner, thereby increasing unnecessary physical activity. Examples may include a badly placed area that is frequently used, such as a supply store or tool area. Such a situation may require several trips to complete a simple task, as opposed to a well-designed workspace with a centrally located tool area. By repeating unnecessary physical activity, an employee may tire prematurely.

A workspace may also contribute to fatigue through environmental stress. Conditions such as extremes in temperature, excessive noise, excessive vibrations, poor lighting, and cramped spaces are all associated with fatigue. In addition, personal protective equipment used to compensate for these factors may contribute to fatigue by increasing body temperature or restricting airflow or movement. Reynolds, Drury and Eberhardt provide a fairly comprehensive listing of various ergonomic factors that affect fatigue. Their findings, for example, show varying rates of fatigue and discomfort for inspectors working on different parts of an aircraft, with the highest rates found in the aft cargo and tail interior areas.17

The Occupational Safety and Health Administration (OSHA) sets limits to most of these stressors, but they are based on the physical characteristics that typify the majority of the population. Ergonomic considerations, as well as situation awareness, are even more of an issue for those who do not fit these generalized characteristics.

11.3.1.4.4 Other Factors

Other innate factors contribute to fatigue. These factors include age, illness, nutrition, and general health. These factors need not be the result of a chronic condition; variations in fatigue may result from daily, situational factors. For example, ingesting a meal high in fats may lower the oxygen content in blood flow by more than 20%, creating a situation akin to hypoxia. This, in turn, contributes to feelings of fatigue.18

11.3.2 Effects of Fatigue

As stated previously, several factors affect fatigue or perceptions of fatigue. However, fatigue may also serve as an independent variable with its own effects on the individual. Fatigue has been linked to several decreases in performance ranging from cognitive to attitudinal to behavioral. Graeber summarizes and categorizes these effects. Table 11.1 is adapted from his work.5

Table 11.1 Effects of Fatigue on Performance (Graeber)

Performance Category	Effects
Reaction Time Increased	Timing errors in response sequences
	Less smooth control
	Require enhanced stimuli
Attention Reduced	Overlook/misplace sequential task elements
	Preoccupation with single tasks or elements
	Reduced audiovisual scan
	Less aware of poor performance
Memory Diminished	Inaccurate recall of operational events
	Forget peripheral tasks
	Revert to “old’ habits
Mood Withdrawn	Less likely to converse
	Less likely to perform low-demand tasks (task aversion)

	More distracted by discomfort
	More irritable
	"Don't care" attitude (complacent)

Fatigue also interferes with training, diminishing one's ability to incorporate new information.19 Decision making may also be impaired.17 Indeed, the effects of fatigue are insidious and wide reaching. Finally, it is important to understand the interaction among and between fatigue, its various effects, and its antecedents. Reynold, Eberhardt and Drury provide a good aviation-related example:17

> ?"...while performing maintenance or inspection in a cramped area of an aircraft, there may be an initial physiological response to the postural demands such as lack of blood flow to the leg muscles, which in turn causes a behavioral response (e.g., posture shifting) and/or subjective response (e.g., perceived discomfort). In addition, such a behavioral response may alleviate one component of the fatigue response, while causing another. Continuing the example, a change in posture may reduce the physiological response, but the new posture may make the task more difficult to perform and cause feelings of frustration."

This excerpt from Reynold et al.'s study provides an excellent example of a situation in which components of fatigue compound on one another, degrading performance, and creating a potentially hazardous situation.

11.3.3 Summary

As can be surmised, fatigue is an imminently familiar, yet loosely defined construct. Several factors interact to contribute to perceptions of fatigue. The factors range from time on duty to workplace factors to one's own general health. This study focuses on a few of the main stressors that may contribute to fatigue, namely "time on duty" and "sleep obtained." This study is exploratory in nature and offers no direct hypotheses. It exists to establish a baseline measure of these fatigue factors for aviation maintenance personnel. In addition, though the survey records instances of fatigue predictors, no direct measurements of fatigue were sought. Therefore, a caveat must be made to limit generalizations made about fatigue based on this current study.

11.4 THE SURVEY

The survey instrument is a 46-item questionnaire. It requires approximately 30 minutes to complete. The primary data of interest were time scheduled, actual time worked (including overtime), sleep obtained, and other hours worked. Additional data were collected as well. Respondents were encouraged to answer questions fully and to the best of their abilities, though they were allowed to skip any questions that they wished. The survey is available in Appendix A.

11.4.1 Respondents

Five hundred-eighteen individuals responded to the survey overall. Table 11.2 summarizes the ranges, means, and standard deviations of most of the sample characteristics. Respondents ranged from 19 to 76 years of age. The average age is 41.6 (σ = 11.0 years). Figure 11.1 displays the distribution of the sample with regards to age.

Overall aviation experience ranges from a minimum of 0 years to a maximum of 56 years. The average years of experience was 18.2 (σ = 11.6 years). Figure 11.2 displays the distribution of the sample with regards to total aviation experience. These data indicate that the sample was highly experienced in aviation maintenance, with approximately 75% of respondents possessing 10 or more years of experience in aviation, while half possessed 16 or more years of experience.

Data was also recorded in terms of years of experience in a respondent's current position. Experience in one's current position ranges from a minimum of 0 years to a maximum of 43 years. The average years of experience was 7.6 (σ = 6.9 years). Contrasting with total overall experience, approximately two-thirds (66%) of respondents who answered this question indicated 10 years or more experience at their current job. Over half (51%) indicated that they have been in their current position less than 6 years. Figure 11.3 displays the distribution of the sample with regards to aviation experience in a respondent's current position.

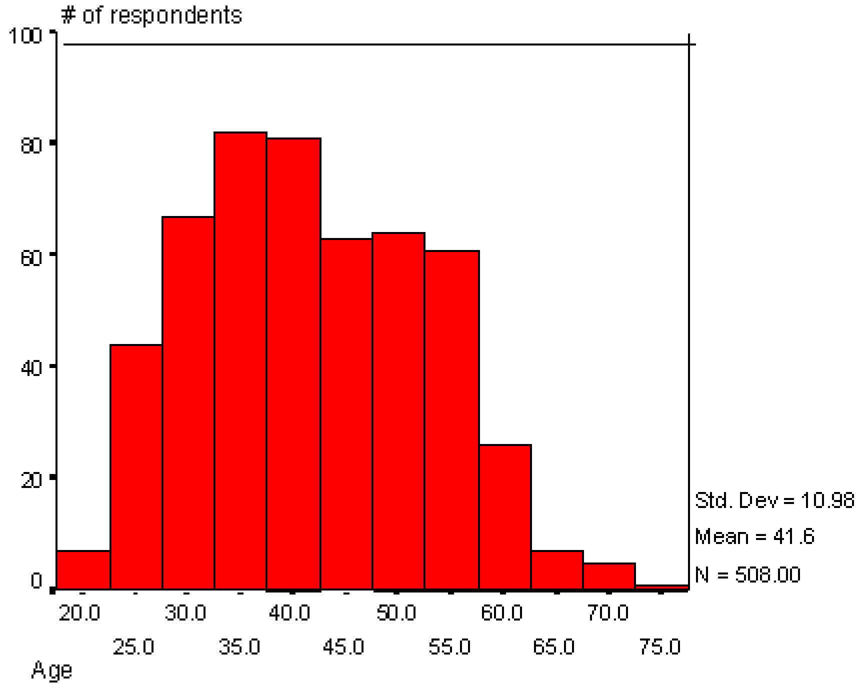


Figure 11.1 Sample Distribution According to Age

Table 11.2 Descriptive Statistics of Respondent Pool

	N	Max.	Min.	Median	Mean	SD
Age	508	19	76	40	41.64	10.98
Total years experience	495	0	56	16	18.22	11.59
Experience in current post.	487	0	43	6	7.77	6.89

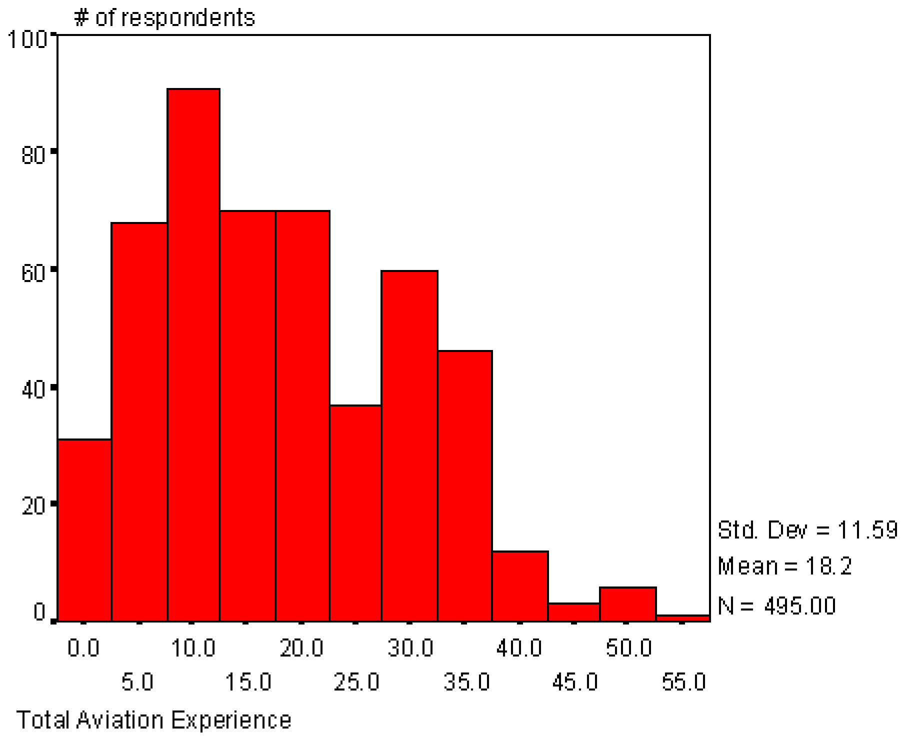


Figure 11.2 Sample Distribution According to Total Aviation Experience

Table 11.3 Marital Status (n=495)

Single	76.2%
Married	23.8%

Table 11.4 Gender (n=507)

Male	95.3%
Female	4.7%

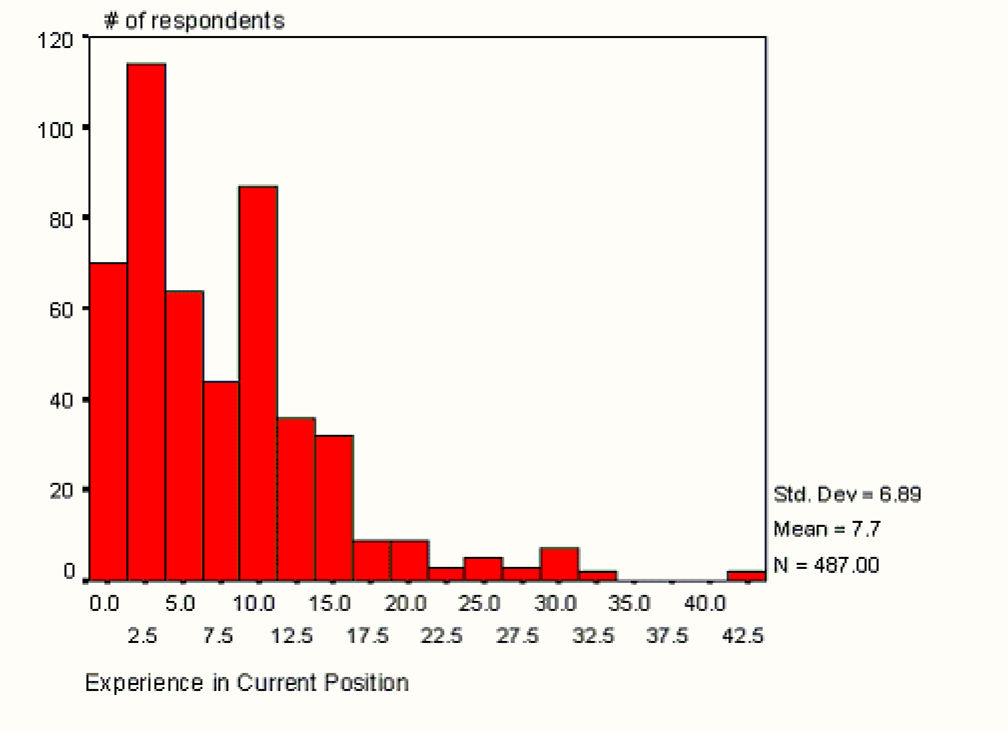


Figure 11.3 Sample Distribution According to Experience in Current Position

The majority of respondents described themselves as working for "major airlines" (48.5%), while those working for repair stations made up the second largest percentage (36.9%). Figure 11.4 shows the breakout of respondents by "Affiliation."

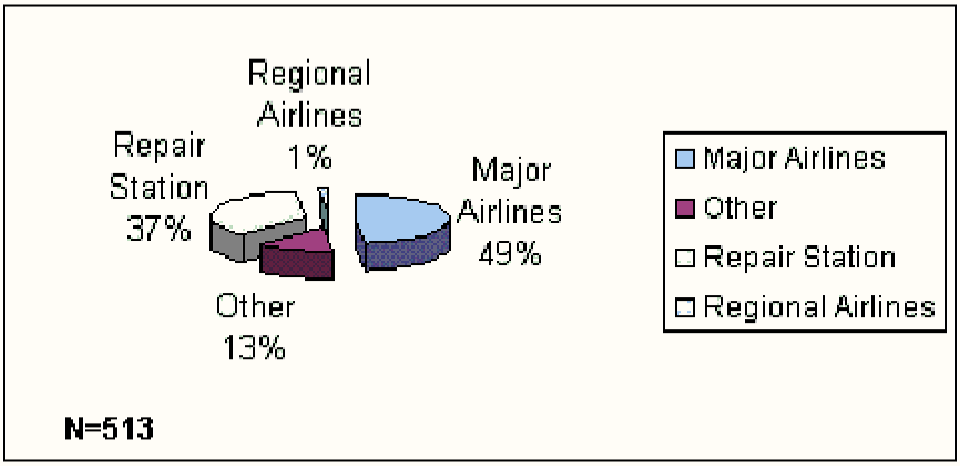


Figure 11.4 Sample Breakout by Affiliation

For "Job Type," the majority of respondents described themselves as working primarily on the airframe (33%), while those performing quality assurance/inspection made up the second largest percentage (21%). Five additional responses were discarded for checking more than one box. Figure 11.5 shows the breakout of respondents by "Job Type."

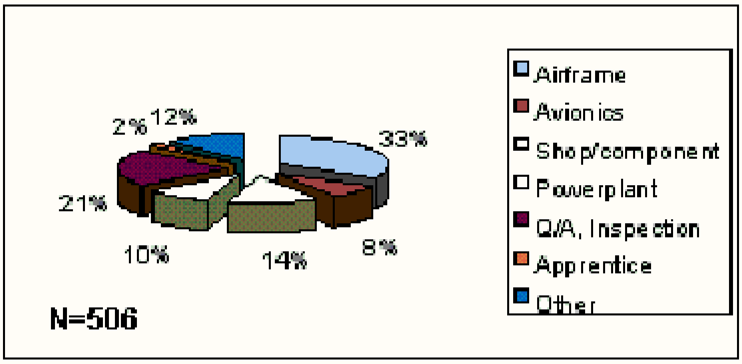


Figure 11.5 Sample Breakout by Job Type

The majority of respondents indicated their primary place of work to be within the shop or hanger. In addition, the overwhelming majority of respondents consisted of "full-time" (workweek of 40 or more hours) employees. See Tables 11.5 - 11.6.

Table 11.5 Location of Job (n=506)

Line	17.19%
Shop/Hanger	82.81%

Table 11.6 Employee Type (n=514)

Full Time	98.64%
Part Time	1.36%

Sixty percent of respondents described themselves as "first shift" employees. A full breakout by shift type is available in Figure 11.6.

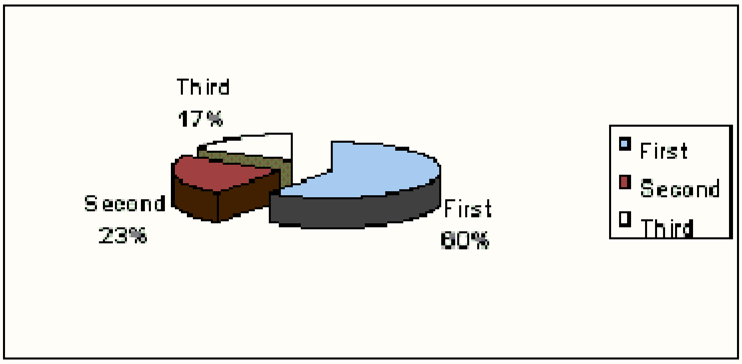


Figure 11.6 Sample Breakout by Shift

Finally, Table 11.7 provides the breakout of respondent job roles by their place of employment.

Table 11.7 Crosstabulation (Job Role by Affiliation): Number of Respondents

		Affiliation				*Total*
		Major Airlines	**Other**	**Regional Airlines**	**Repair Station**	

Role	**Q/A Inspection**	55	16	1	36	180
	Airframe	96	25	2	44	167
	Apprentice				12	12
	Avionics	23		1	14	40
	Powerplant	29	4		15	48
	Shop	11	1		58	70
	Other	23	21	3	12	59
Total		237	69	7	191	504

The largest group of respondents is categorized as specializing in airframe work for major airlines. Job categories were distributed relatively evenly among the facility types, with the exception of a large amount of shop employees affiliated with repair stations.

Total aviation experience was evenly distributed among affiliations. However, a greater percentage of repair station employees (42.5%) had 6 years or less experience in aviation as compared to 15.5% of those working for major airlines. Overall, though, respondents were a highly experienced group. Table 11.8 shows these data in more detail. For the sake of readability, "total experience" was divided into quartiles.

Table 11.8 Crosstabulation (Affiliation by Total Aviation Experience)

		Total Experience				*Total*
		A	**B**	**C**	**D**	
Affiliation	*Major AL*	37	65	69	68	239
	Other	6	14	21	25	66
	Regional	4		2		6
	Repair St.	77	44	34	26	181
Total		124	123	126	119	492

Group A= 9 years or less
Group B= 9-16 years
Group C=16-28 years
Group D= more than 28 years

Respondents were recruited via 2 trade organizations using one of two methods. The first method entailed sending copies of the survey to managers of AMTs. These managers distributed the survey to floor-level employees at their discretion.

The second method utilized direct mailing of 1000 surveys to individuals. Response rate for this set was approximately 30%. Completion of the survey for both groups was totally voluntary.

The methods used to recruit the subject sample demonstrate the primary limitation of the current study. The study does not represent a random sample of aviation maintenance technicians. The effects of this fact are presented in greater detail in the Discussion section of the paper.

In addition, respondents were not required to divulge information that they felt intrusive, in accordance with American Psychological Association recommendations. As a result, many questions in individual surveys were left blank, thereby creating differential sample sizes among survey data.

11.4.2 Results

The main questions of interest were how many hours were respondents working, how much sleep they were getting, and whether they sought to work these particular hours. Table 11.9 shows the descriptive statistics for these variables.

Table 11.9 Descriptive Statistics (Hours of Work and Sleep)

	N	Mean	Median	Mode	SD
Hours per week	279	49.44	48	40	9.23
Hours per day	489	8.49	8	8	.93
Hours of sleep (workday)	510	6.69	7	6	1.13
Hours of sleep (non-workday)	508	7.96	8	8	1.28

Respondents, on average, worked more than the normal 40 hour work week, with almost a fourth working 52 or more hours. Less than a fourth of respondents (24.7%) worked 40 hours (or less) a week.

Twenty-five percent of respondents were sleeping six hours or less per work night, while 22.3% of respondents received eight or more hours of sleep per work night. The numbers were expectedly higher for non-work nights, with less than one-third receiving 7.5 hours or less sleep per night.

Table 11.10 shows the breakout across affiliation for hours worked per week. For the sake of readability, hours were collapsed into separate classes approximating percentile groupings.

Table 11.10 Crosstabulation (Affiliation by Hours per Week Worked)

		Hour per Week				*Total*
		A	**B**	**C**	**D**	
Affiliation	**Major AL**	49	22	14	18	103
	Other	3	11	9	9	32
	Regional		2	1	1	4
	Repair St.	19	35	44	40	138
Total		71	70	68	68	277

Group A= worked less than 42.5 hours
Group B= worked between 42.5 and 48 hours
Group C= worked between 48 hours and 52 hours
Group D= worked more than 52 hours

The columns labeled A, B, C, and D represent quartile groupings of the respondent sample as a whole. The numbers represent the actual number of shift employees who work said number of hours. For example, 49 employees affiliated with major airlines work 42.5 hours or less per week.

Of the respondents who answered this question, the most notable differences exist between those who work for major airlines and those who work for repair stations. Over 60.9% of repair station employees worked 48 or more hours a week, as compared to 31.1% of those who work for major airlines. The other two categories were more evenly split, though their low sample sizes affect data interpretation.

A General Linear Model (GLM) was also performed for weekly work hours (dependent variable) by affiliation (independent variable.) GLM was chosen due to the uneven cell sizes among groups. No significant difference was found between groups overall. In other words, employees, regardless of affiliation, worked approximately the same number of hours per week.

However, because GLM only shows that significant differences exist between factors (variables) of the group overall, a tukey post hoc test was also performed. The tukey post hoc indicates that repair stations employees work significantly more ($p<.05$) than employees of major airlines. More specifically, repair station employees worked 3.2 more hours per week than those employees of major airlines. Table 11.11 shows the results of the tukey post hoc.

Table 11.11 Tukey post hoc of work hours by affiliation

		Mean Difference (A-B)	*Std. Error*	*Sig. (alpha)*
Group A	**Group B**			
Major Airline	Other	-2.79 hrs	1.85	.44
	Regional Airline	-2.01 hrs	4.67	.97
	Repair Station	-3.16 hrs*	1.19	.04

Based on observed means.
* The mean difference is significant at the .05 alpha level.

Table 11.12 shows the breakout of job role by hours worked per week. Percentage-wise, those listing themselves as “other” and “shop” employees had work weeks that consisted of more than 42.5 hours, accounting for 92.3% and 81.0% of respondents respectively. However, these two categories as a whole accounted for only 27.8% of the total. Even so, other larger job categories scored comparably with the majority of airframe (75.3%), avionics (76.2%) and powerplant specialists (75.0%) all working more than a 42.5 hour work week. Inspectors (61.2%) and students (50%) ranked the lowest overall.

Table 11.12 Crosstabulation (Job Role by Hours per Week): Number of Respondents

		Hours per Week				*Total*
		A	**B**	**C**	**D**	
Role	**Q/A Inspection**	21	16	8	10	55
	Airframe	24	29	23	24	97
	Apprentice	3		2	1	6
	Avionics	5	3	4	9	21
	Powerplant	7	4	11	6	28
	Shop	8	12	13	9	42
	Other	2	8	6	10	26

Total		70	69	67	69	275

Group A= worked less than 42.5 hours
Group B= worked between 42.5 and 48 hours
Group C= worked between 48 hours and 52 hours
Group D= worked more than 52 hours

Focusing on Group D (worked more than 52 hours), 42.9% of avionics specialists worked 52 or more hours a week, the greatest percentage of all job categories. One possible explanation may lie in the shortage of avionics specialists as whole within the AMT community. Such a shortage would create a strain on existing manpower attempting to compensate.

The breakout of hours worked by shift shows a relatively even distribution across shift types. For example, 48.5% of first shift employees worked 48 or more hours per week, as compared to 48% of second shift and 33.3% of third shift employees. These data do not support the anecdotal assumption that third shift employees work more hours than others.

A GLM analysis was performed to examine the hypothesis that employees in specific shifts work more or less than others. GLM indicated no significant differences among the weekly hours worked by a particular shift. See Tables 11.13 - 11.14 for the full breakout.

Table 11.13 Means of Hours Worked per Week Categorized by Shift

Shift	*N*	*Shift Means*
First	163	49.59 hrs/week
Second	77	49.99 hrs/week
Third	36	47.58 hrs/week

Table 11.14 Crosstabulation (Shift Type by Hours per Week Worked)

		Hour per Week				*Total*
Shift		**A**	**B**	**C**	**D**	
	First	38	46	42	37	163
	Second	18	22	17	20	77
	Third	13	11	5	7	36
Total		69	79	64	64	276

Group A= worked less than 42.5 hours
Group B= worked between 42.5 and 48 hours
Group C= worked between 48 hours and 52 hours
Group D= worked more than 52 hours

The hours of sleep when shifts are taken into account are more telling. A greater proportion (66%) of third shift employees (n = 84) receive six or less hours of sleep on a workday than either first shift (40.3%, n = 300) or second shift (34.0%, n = 118). These results support the assumption that those required to sleep during the day do not receive as much sleep as their counterparts.

According to General Linear Model (GLM) analysis, a significant difference exists among shift types for sleep on workdays [F(2,499) = 16.47]. GLM was chosen due to the unequal cell sizes used for comparison.

Table 11.15 shows the results of a Student-Newman-Kuels (SNK) post hoc test. Each column labeled *A*, *B*, or *C* represents groupings that are significantly different. The post hoc test indicates that third shift employees sleep less than first shift employees (6.13 hours/night vs. 6.72 hours/night.) Second shift employees sleep the most of all, sleeping an average of 7.02 hours per night.)

Table 11.15 Results of Student-Newman-Keuls Post Hoc

	N	*Subsets*		
Shift		*A*	*B*	*C*
Third	84	6.13 hrs.		
First	300		6.72 hrs.	
Second	118			7.02 hrs.

a. Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = 1.206.

b. Alpha = .05

Curiously, closer inspection of "Hours Worked per Day" (n = 489) reveal trends more similar to the "normal" shift. The majority of respondents (66.1%) work eight hour days. Less than a third (32.2%) work more than 8 hours a day.

These data may seem incongruous until the "number of days worked" during a shift is taken into account. Indeed, 49% of respondents who answered this question (n = 147) work six days a week. "Days Worked per Week" is illustrated in Table 11.16. In short, though the majority of respondents are working roughly eight hour daily shifts, they are working more days than the "typical" five day work week. This extra day (or in some cases two) accounts for the number of employees working more than 40 hours per week.

Table 11.16 Number of Days Worked in a Week

	Frequency	*Valid Percent*	*Cumulative Percent*
4 days	3	2.0	2.0
5 days	43	29.3	31.3
6 days	72	49.0	80.3
7 days	29	19.7	100.0
Total	147	100.0	

In fact, 65.5% of those affiliated with major airlines and 72.9% of those affiliated with repair stations report work weeks of 6 days or more. Separated by job type, the greatest percentage of powerplant specialists (76.5%) work 6 or more days a week. Table 11.17 shows the breakout.

Table 11.17 Respondents' Work Week

Job Type	**Total sample**	**Working 6+ days per Week**
Q/A Inspection	16	12, (75.0%)

Airframe	52	39, (75.0%)
Apprentice	4	2 ,(50%)
Avionics	7	5, (71.4%)
Other	7	8, (47.1%)
Powerplant	17	13, (76.5%)
Shop	31	22, (71.1%)
Total	144	101, (70.1%)

Respondents were also asked if they worked other jobs or attended school. Of the total (n = 504), 82.9% indicated "no." The remaining 15.1% varied widely in the amount of times these other activities required. Table 11.18 illustrates these data. Two respondents who checked "yes" did not indicate any hours.

Table 11.18 Descriptive Statistics for Hours/Week Spent on School/Other Jobs

	N	**Max.**	**Min.**	**Median**	**Mean**	**SD**
Hours/week (other activity)	74	1	41	8.5	12.35	9.5

Further analyses were performed examining the relationship between experience and hours worked daily and weekly. A significant negative relationship was found between experience and hours worked per week. In other words, the least experienced employees were working the most hours per week. The relationship between daily hours, however, was non-significant, but may be explained by the preponderance of respondents working eight hours per day. As expected, "Total Experience" and "Experience in Current Position" were highly correlated. Table 11.19 presents the correlation matrix.

Table 11.19 Correlation Matrix

	Total Experience
Total Experience	--
Weekly hours	**-.134***
	N=270
Total daily hours	.119*
	N=252
Current position	**.539****
	N=475

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Total experience was not a good predictor, however, of work in other jobs or school. "Other Work" was evenly distributed among all four categories of experience as is shown in Table 11.20.

Table 11.20 Crosstabulation (Total Aviation Experience by Other Work)

		Total				*Total*

		Experience				
		A	**B**	**C**	**D**	
Other Work	**Did Not Answer**		5	3	4	12
	No	101	98	101	109	409
	Yes	24	21	22	7	74
Total		125	124	126	120	495

Group A= 9 years or less
Group B= 9-16 years
Group C=16-28 years
Group D= more than 28 years

Employees' attitudes towards duty time were examined. Means and standard deviations for these questions are presented in Table 11.21.

Table 11.21 Descriptive Statistics of Answers to Attitudinal Survey

	N	**Mean**	**SD**
6.1 I work fewer hours than my immediate coworkers...	496	2.23	1.06
6.2 I often work double (or more) shifts.	493	1.96	1.05
6.3 Management often asks me to work more than 40 hours...	493	3.24	1.23
6.4 I would like to work more hours a week...	498	2.76	1.13
6.5 I would like to work fewer hours a week...	497	2.81	1.16

Questions 6.4 and 6.5 are the same question, phrased in the opposite manner. This was done as a manipulation check. As was expected, there is a significant negative correlation ($r = -.456$, $p<.01$) between the two data points.

Correlations were performed between the answers to questions 6.1-6.5 and other demographic data. The demographic data of interest were "hours worked per week," "sleep obtained on a workday," "total aviation experience," and "experience in current position." The correlation matrix is presented in Table 11.22.

Table 11.22 Correlation Matrix for Attitudinal Survey and Other Variables

Variable	**6.1**	**6.2**	**6.3**	**6.4**	**6.5**
6.1 I work fewer hours than ...	--				
6.2 I often work double shifts...		--			
6.3 Management often asks me to...	**.133****	**.159****	--		

	N=489	N=488			
6.4 I would like to work more ...	**-.126****	**.166****		**--**	
	N=494	N=493			
6.5 I would like to work fewer...			**.184****	**-.456****	**--**
			N=491	N=496	
Total hours worked per week	**-.245****	**.151***			**.150***
	N=267	N=266			N=268
Hours of sleep (workday)		**-.117****			
		N=493			
Total aviation experience			**-.184****	**-.238****	
			N=473	N=478	
Experience in current position				**-.209****	**.121****
				N=470	N=470

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Some of the relationships among the data presented in this section make intuitive sense. For example, those respondents who indicated that they work fewer hours than their colleagues do also tend to work less hours overall. In addition, those who are asked by management to work double shifts tend to work double shifts. These same workers also work more hours per week and sleep less on workdays. This relationship was not found to be associated with job experience.

However, a significant negative relationship exists between total job experience and being asked to work double shifts. In other words, those with less job experience were more likely to respond that management asked them to work double shifts. In addition, those who were asked by management to work double shifts also indicated they wished to work fewer hours than their present schedule. No correlation was found, though, with experience in one's current position. Finally, a significant positive relationship exists between questions 6.2 and 6.4, indicating that those who do work double shifts also desire more hours in their present schedule. No such relationship exists between those who work double shifts and those wanting fewer hours.

On the surface, this relationship also makes intuitive sense. It is possible that those who wish to work more hours are purposely working double shifts. But the positive relationship between questions 6.3 and 6.5 could indicate that the wrong employees are being asked by management to work double shifts. It must be understood, however, that, while question 6.3 asks if management is demanding double shifts from employees, there is no direct metric measuring if this is actually taking place.

One final relationship of note is the significant correlation between desire to work and job experience. These data indicate that those with more experience would like to work less hours, while, conversely, those with less experience would like to work more hours. Once again, this result makes intuitive sense.

One caveat regarding these data must be submitted, however. Most of these relationships, though significant, are modest at best. Statistical significance may be an artifact of sample size.

Nevertheless, a closer examination of these relationships can still provide guidance for future research.

Finally, analysis was performed using a General Linear Model (GLM). GLM was chosen due to the unequal sample sizes of each grouping (for independent variable.) GLM demonstrates a significant difference for Q 6.3 between those affiliated with major airlines and those with repair stations [$F(4,1) = 10.98$, $p<.01$.] Those who work for major airlines scored a mean of 2.92, while employees of repair stations averaged 3.67.

GLM also shows a significant difference exists among job roles for Q 6.5, $F(7,1) = 4.13$, $p<.01$. Employees who classified themselves as "powerplant," "avionics," or "other" specialists scored significantly greater than other employee types. Table 11.23 presents the means for each job role.

Table 11.23 Results from GLM Analysis of Job Roles for Q. 6.5

Job Role	N	Mean (Group A)	Mean (Group B)*
Apprentice	10	2.1	
Shop	70	2.29	2.29
Airframe	161	2.79	2.79
Q/A Inspection	104	2.88	2.88
Avionics	39		2.97
Powerplant	47		3.09
Other	55		3.15

Significant, p=.052 (results of a Student Newman-Keuls post hoc analysis)

These results indicate that avionics, powerplant, and "other" specialists disagreed less with Q 6.5 ("I would like to work fewer hours per week, including overtime.") It must be noted that despite significant differences found among groups, all means range from disagreement to neutrality with Q 6.5. In other words, in general, none of the respondents desired to work fewer hours than their current assignments.

A chi-squared analysis was also performed to investigate respondent trends for questions 6.1-6.5. A significant majority of respondents disagreed with question 6.1, X^2 (4, n = 496) =172.35, p<.01. Of the sample, 62.9% indicated disagreement. In short, respondents believed that co-workers shared similar or more hours.

Likewise, a significant majority of respondents disagreed with question 6.2, X^2 (4, n = 493) = 275.12, p<.01. Of the sample, an even greater majority than question 6.1 (73.0%) indicated disagreement. These data support earlier findings showing the majority of respondents conform to a daily eight hour shift.

A significant majority of respondents agreed with question 6.3, X^2 (4, n = 493) = 67.05, p<.01. Of the sample, 62.9% indicated disagreement. Responses for this question were fairly evenly distributed, though 32.3% of individuals demonstrated "agreement" with the question.

The majority of respondents for questions 6.4-6.5 indicated neutrality. Of the sample, 33.5% checked "neutral" for Q 6.4, X^2 (4, n = 498) =104.39, p<.01, while 38% checked the same for Q 6.5, X^2 (4, n = 497) =120.74, p<.01.

11.5 DISCUSSION

The results of this study paint an interesting picture of the state of aviation maintenance industry. In short, the AMTs who responded to this survey work more than the "typical" 40-hour work week. When part-time workers are factored out, the mean and standard deviation for hours work both truncate (mean = 49.5, SD = 9.1). A closer examination of the data shows that while 20.4% (n = 56) work 40 hour weeks, the next most common answer was a 50 hour work week, representing 18.6% (n = 52) of respondents who answered this question. In fact, 47.3% of respondents (n = 132) stated they worked 50 or more hours per week.

The results, however, do not point to extended daily duty times. According to these data, the typical respondent works between eight and nine hours a day, though he or she may only have one day off per week.

Attitudinal data derived from this study also points to particular trends among AMTs. First, respondents demonstrated a marked sense of neutrality when it came to their own work hours; they did not wish to work significantly more or less hours than their current schedules. However, the large number of "neutral" answers to these questions could be the result of a central tendency bias, or perhaps, an artifact resulting from respondents' skepticism of what the survey's ultimate use will be.

Future studies should account for the hesitancy in individuals' response patterns, especially when gathering data on such sensitive material as duty time assignments and, ultimately, employees' paychecks. Additional studies can make more use of focused visits, in which the researcher would rely less on third parties to collect data and, instead, be on-site for survey administration. Though the resulting sample may not be as large or diverse, respondents may be more willing to answer sensitive or intrusive questions.

The data regarding sleep habits indicate respondents may not be acquiring the optimum amount of sleep per night. Respondents averaged 6.67 hours per night of sleep. However, these numbers may reflect the sleep habits of the population as a whole. A survey conducted by the National Sleep Foundation found that 35% of Americans acquired less than eight hours of sleep per day, while 30% sleep less than six and a half hours on a work night.[20,21] It may be possible that AMTs' sleep habits are indicative of the overall population's sleep habits. However, no data were collected with regards to why AMTs might be encountering a sleep deficit.

The relationship between hours worked and sleep on workdays was non-significant, though a significant positive correlation was found between the hours one worked per week and hours slept on non-workdays ($r^2 = .161$, $p<.01$, $n = 274$). Such data may indicate that respondents may be attempting to catch up on "sleep debt" accrued over the week. Though one should be wary when making conclusions based on correlational data, logically it makes sense. The converse, sleeping more leads to more hours at work, does not follow. However, a third intervening variable may be present.

One final set of data was collected during this study. These data include free-form comments provided by the respondents themselves. Though these comments are subjective in nature, they provided a fair look into the issue of duty times. Approximately one-quarter (25.8%, n=131) of respondents added comment to their surveys. Many of them were cogent, well thought-out and greatly enriched the objective data.

A small percentage of the comments revolved around the issue of safety and "working too many hours." These comments are generally separated into those attributing extended duty times to lack of personnel, lack of adequate pay, or scheduling pressures. A sample of these comments follows:

> ?"With reduction in force (due to) downsizing, there is no other way to meet organizations goals/milestones without working 10 hr. days. I only charge for 8 hr day."?

> ?"When younger, low pay requires you to be willing to work lots of overtime. Thank God I don't now have to rely on O.T. to survive. Age does make it easier to say No to O.T. There should be requirements for crew rest for maintenance folks. Working 16-24 hours is not safe for anyone."?

?“No set time. I am a corporate maintenance technician and I am basically on call 24 hours a day. When an aircraft is broken I must stay until it is repaired. My fatigue level, or lack of rest has never seemed to be a factor to the chief pilot(s). There has always been said and unsaid pressure to get the aircraft back in service. The pilots have always been concerned over their duty times. Many times I've worked when I felt I was too fatigued.”

These comments represent a knowledgeable and conscientious workforce. Other comments mentioned supervisory policies in place that already limit duty time assignments.

?“Overtime with my supervisor is generally expected when required, but not mandatory. Personally, I see overtime as opportunity. I feel safety is a primary concern of my employer and would not be compromised by excessive workloads. Company policy forbids working more than 12 hours in any one day. Maybe regulation would be needed for companies without a stated policy, but not forced on a company that already has a policy.”

?“My family is a one income household. I usually volunteer for overtime to support my wife and children. My supervisors frequently allow me to adjust my schedule to accommodate my needs (which) includes time off to rest if necessary.”

A greater majority of respondents, however, used the “Comments Section” to vocalize the need for more desirable work conditions. Several of these comments called for “longer shifts and shorter work weeks.”

?“If I had a choice I would prefer to work a scheduled 10 hr day on 3rd shift. This would allow for a 3 day weekend. And a healthier transition from a night routine to a day routine with my family. (One extra day on your weekend to allow for a night/day transition then two days for a normal "day" routine.)”

More comments lamented the variability of the AMTs schedule, particularly for those working for corporate aviation departments or others “on call.”

?“On call for inspection and repair, teaching new techs (A&Ps) the things no longer taught in school -- do not think that I/we can keep this up much longer.”

??“(I) work for a corp. flight dept. Hours range from early mornings to late. Corp. flight Dept. do not have the luxury of scheduling hours, you are required to be there. This could sometimes cause long days and several days on with no time off.”

??“Duty hours fluctuate quite frequently from day to day flight departure & arrival times. Personnel can find themselves retrieving, late in the evening and scheduled back to work the following day for a early morning departure.

Still others discussed the downsides of Rotating Days Off (RDOs) and the difficulties of working during third shift.

Other respondents explicitly stated the voluntary nature of their overtime:

?“Most overtime here is strictly voluntary. I appreciate overtime and I protect it vigorously.”

?Others were even more vociferous about their protection of overtime:

?“The government has no business mandating work hours or schedules.”

The comments, taken together as a whole, show an issue of great complexity. Though many recognize the link between duty times, fatigue and safety, other factors also interact within the equation. These components include, but are not limited to, staffing, pay, job ambiguity, scheduling, and quality of life issues.

11.5.1 Conclusion

This study remains a first, exploratory step in examining duty times in the aviation maintenance community. It is not meant to be used for establishing regulatory guidelines, but rather to steer future research in this area. Such research should incorporate a more rigorous methodology that compensates for inherent limitations built within this study's survey design.

Several new avenues of research are possible. First, it is possible to obtain metrics of duty times via employee records. Though considerably more intrusive than this study, the resulting data should be a more reliable indicator of time on the job. However, such gross measures should be coupled with attitudinal data, so as to gain a better understanding of the interaction of duty times and other job and personal-related factors. These attitudinal measures could include indexes of job satisfaction such as the Job Description Index (JDI) or the Minnesota Job Satisfaction Questionnaire. Using this multi-dimensional approach to human performance, one can create a robust statistical model to establish the role of duty time assignments as a predictor of human performance.

Second, though respondents were queried as to their sleep habits, no direct measures of fatigue were taken for this study. Future research should try to incorporate reliable measures of fatigue in order to replace the inferred relationship between duty times and fatigue with more rigorous metrics. For example, future research may record physiological measures of fatigue. In addition, because duty time assignments are but one factor related to fatigue, other job-related characteristics, such as information-processing demands, could also be gauged.2

Future studies should include measures of performance as well. Performance measures vary wildly from study to study; many of them depend on the unit of measurement (e.g., workgroup or individual.) However, certain common performance measures, such as rates of on-the-job injuries, absenteeism, turnover, delays in schedule, rates of equipment damage, etc., could be joined to future studies of duty time. This can provide further evidence that would support (or not support) the link between duty times and safety. In addition, these data can be used to generate models to determine the utility (i.e., economic impact) of qualities that characterize particular organizations. This would no doubt be of the greatest benefit for the aviation community as a whole.

The ability to focus prospective research into the areas that would result in the greatest return on investment is this study's greatest asset. For example, differences seem to be most salient between certain affiliations (major airlines and repair stations) and for particular job types (avionics specialists.)

In addition, the limitations of the study preclude making sweeping generalizations about the AMT community. Primary among the limitations is the use of a non-scientifically sampled survey population. Respondents voluntarily completed and returned the survey; the characteristics of such individuals may be different than the AMT community overall. For example, the majority of the sample work during the first shift. It is also an accepted work practice to assign senior technicians to the first shift. Sample characteristics such as these may affect the data and limit this study's generalizability. However, this study still goes beyond anecdotal evidence such as of "stories" and case studies. The current study demonstrates the interaction among of such variables as experience, age, duty time, affiliation, and job type, for example. In that, it presents a valid assessment of the aviation maintenance industry.

In conclusion, this study stresses the complex nature of duty assignments, fatigue, and human performance. From these data, it seems inappropriate to point to duty times as a singular problem. It seems that the length of the AMT's daily shift is less of an issue than the number of days worked without a "break." However, from the comments, respondents overall seem to enjoy their jobs or enjoy the work that they are doing. We only need to continue to isolate and examine those factors that will help these same people work even better.

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11.7 APPENDIX A Copy of Survey

Please read the following questions carefully and thoroughly. All responses will remain anonymous. Try to answer each question. However, if any questions make you uncomfortable, you may skip them. Thank you for your time.

Section 1. General Information

Gender (check appropriate box): q male q female

Age: ________ Marital Status: ___________________________

Which facility type best applies to your current job (Please check only one box).

q Major Airline q Repair Station
q Regional Airline q Other

Primary Role/Position (Please check only one box.)

q Airframe q Powerplant q Other
q Avionics q Q/A, Inspection
q Shop/Component q Apprentice (Student)

In which location do you perform most of your duties? (Please check only one box).

q Line q Shop/Hanger

Years of Aviation Experience _____ Years of Experience in *Current* Position ______

What type of employee are you? (Check only one.)

q Full-time (40 or more hours per week) q Part-time (less than 40 hours per week)

Section 2. Duty Time Information

The following questions gauge your duty time and the amount you work. Please fill out the survey completely and honestly. All responses will remain anonymous.

2.1 Circle which shift you primarily work in. 1st 2nd 3rd

2.2 Please circle which days you *should normally* be scheduled to work (without overtime). A "normal" work week is defined as working 40 hours.

Mon. Tues. Wed. Thurs. Fri. Sat. Sun.

2.3 If you work with Rotating Days Off (RDOs), please check this box q and skip to the next question (2.4).
Day of Week Your Shift Begins: _______ Day of Week Your Shift Ends: ________

2.4 Please state the times of your *normal* daily shift (without overtime).
Daily Starting Time: ________ am/pm (indicate morning or evening)
Daily Ending Time: ________ am/pm

(If you should start your day at different times during the week, please indicate how in the space below.)

2.5 Total Hours Scheduled Daily: ______

Section 3. Overtime Information

This section estimates the amount of overtime you work in an average week.

3.1 If you do not work typically work overtime, check this box q and go to Section 4.

3.2 Please estimate how long your *actual* duty time is per week (in hours) _____

3.3 Please circle which days you *actually* work (including overtime):
Mon. Tues. Wed. Thurs. Fri. Sat. Sun.

3.4 If you work with Rotating Days Off (RDOs), please check this box q and skip to the next question (3.5).
Day of Week Your Shift Begins: _______ Day of Week Your Shift Ends: ________

3.5 Please state the times of your *actual* daily shift (including overtime).
Day of Week Shift Begins: _____ Day of Week Shift Ends: ________

Daily Starting Time: ________ am/pm (indicate morning or evening)
Daily Ending Time: ________ am/pm

(If you typically start your day at different times during the week, please indicate how in the space below.)

3.6 Total Hours Worked Daily: ______ 3.7 Total *overtime* hours worked *per week*: _________

Section 4. Previous Week Information

This section relates to your last full work week.

4.1 How many hours (total) did you work last week? _____

4.2 Please circle which days you worked last week (including overtime):
Mon. Tues. Wed. Thurs. Fri. Sat. Sun.

4.3 If you work with Rotating Days Off (RDOs), please check this box q and skip to the next question (4.4).
Day of Week Your Shift Began: ______ Day of Week Your Shift Ended: ________

4.4 Please state the times of you worked last week (including overtime).

Daily Starting Time: ________ am/pm (indicate morning or evening)
Daily Ending Time: ________ am/pm

(If you started your day at different times during the week, please indicate how in the space below.)

____

4.5 Total Estimated Daily Hours Worked: ______

4.6 How representative of your typical work week was last week?

- q more hours than usua
- q about the same
- q less hours than usual

Section 5. Miscellaneous Information

This section asks various questions that relate to the amount of rest you get.

5.1 Please write down the most number of days in a row you have worked in the past 6 months.

______

5.2 Do you work on rotating shifts? (Check box.) q Yes q No

(If Yes, indicate which type below.)

Check only one below.	**Check only one below.**
I change to a new shift: q Weekly (shifts change once a week) q Bi-weekly (shifts change every two weeks) q Monthly (shifts change once a month)	Shifts rotate: q Forward (your new shift starts later than previous shift.) q Backward (your new shift starts earlier than previous shift.)

5.3 Estimate the average amount of sleep you get per 24 hours on a work day (in hours.) _____

5.4 Estimate the average amount of sleep you get per 24 hours on a non-work day (in hours.) _____

5.5 On your days off, do you tend to go to bed at the same times as when you are working?
q Yes q No

If "No," do you go to sleep *later* or *earlier* than your usual time? q Later q Earlier

5.6 Do you have any other jobs or go to school? (Check box.) q Yes q No

If yes, how many hours per week do you work at that job or attend school? _______

5.7 What are your typical number of meals in 24 hours? ______

5.8 What are your typical number of meals during working hours? ______

Section 6. Agree/Disagree

Please check the box that corresponds to your answers.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
6.1 I work fewer hours than my immediate coworkers (on the same shift).	q	q	q	q	q
6.2 I often work double (or more) shifts.	q	q	q	q	q
6.3 Management often asks me to work more than 40 hours a week.	q	q	q	q	q
6.4 I would like to work more hours per week (including overtime).	q	q	q	q	q
6.5 I would like to work fewer hours per week (including overtime).	q	q	q	q	q

If you wish to share any additional comments relating to your duty time, please write them in the space below. If you need more space, you may use the back of this paper. Thank you again for your participation.

____

____

____

____

11.8 APPENDIX B Respondent Comments (Sanitized of Organizational Identifying Information)

This form does not really fit my employment situation I own XXX. Most weeks 3-4 days is all the time I need to schedule. However, some weeks are full of long days.

I must work to make ends meet due to low pay.

I'm a part-time aviation maintenance instructor at XXX.

The daily travel time to work and back takes up to 2 hours a day.

The last time I worked overtime was '89 or '90 and only for about 20 minutes.

I do volunteer work for XXX. I am a retired design engineer.

A work week starts Saturday morning. I work 40 hours (no overtime allowed) for the week. The schedule is variable depending when the planes come and go (corporate flight). If I hit 40 hours before Friday midnight, I am off for the rest of the week.

Being in a corporate flight dept. And as director of maintenance, I am subject to calls and flight problems anytime of day or night. This is especially true if the aircraft is overseas. So although my "work" hours are reflected, my on-call hours aren't.

As a former CEO said, "All plans are firm until changed." This is normal in corporate aviation.

These questions don't really pertain to a corporate operator. My hours are all over the place. Some mornings in at 5 am; some days I don't start till 11:30 PM. I have put in several 24 hours days.

I believe maintenance people flying with aircraft are often required to work exceptionally long days which creates a very dangerous situation.

Every day in corporate aviation changes on an hourly basis, I work late night or work early and I don't go in at a regular time. I also get comp time for working a weekend day.

Note: both F/T and P/T/ jobs with major airline. F/T is hanger; P/T is line maintenance. Experience: 1.5 hanger MX, 3.5 line MX.

In an ideal world, I would prefer to work 35-40 hours per week and receive the same amount of $$$. What a dream!

Haven't worked overtime since March 98. Overtime should open once we settle our contract.

Use comp time in addition to overtime. Comp time policy: employee convenience 1hr wk=1hr comp; company convenience 1hr wk= 1.5 hr comp

I operate a vintage aircraft repair facility. Also do float plane mx, inspection. My hours vary according to whatever task I am working on.

Overtime is occasional, not steady.

I don't mind working an extra 2 hours per day overtime, but I don't like working on the weekend.

I am close to retirement so I do not do the overtime. But I feel the pressure of doing is excessive due to several reason, primary reason pay and economy.

Just need 40 to support self.

I am a lead my OT varies from day to day and aircraft to aircraft.

Shift I work is fine but hours depend on work usually stay hate to paint part's but don't mind working hate cause I like to see progress I have made.

Concerning overtime; I prefer to work a 40 hour week with no overtime.

This survey was not thoughtout or presented very well questions asked can be found on company time clock/computer/payroll. It was a good waste of 10 minutes on work time!

The government has not business mandating work hours or schedules.

I have diagnosed sleep disorder and have doctor's orders for reduced overtime.

Please send me information on how to work more hours.

My family is a one income household. I usually volunteer for overtime to support my wife and children. My supervisors frequently allow me to adjust my schedule to accommodate my needs include time off to rest if necessary.

Hours worked vary by workload. Some weeks hours worked may only be 40 or less hours. Others, hours can exceed 65-70 in a week. Hours worked will also change w/shift rotation in July.

None

Commute time my normal day starts at 0400 and I do not get home until 1715 on work day 13.25 hrs.

Most overtime here is strictly voluntary. I appreciate overtime and I protect it vigorously.

Less then usual hours last week due to holiday and personal things going on.

Not to wear coveralls when not doing a task that is dirty.

A daycare should be built onsite here at XXX. Parking for trucks should be in the back cars in the front and back.

My shift 6:30 to 3:00 Mon thru Fri. is set up by my company. My overtime is consistent and dictated by me and workload in my shop.

I personally like the work hours of 4 days 10hrs each day. The extra family time and relax time away from the hectic and frustrating job site is essential. It usually takes about one day to recover from the work week.

Nobody should regulate the amount of overtime to be worked other than the individual themselves.

Overtime is most often voluntary.

Mandatory overtime is not justified with work load.

Management should take work force into consideration when making contacts with airlines.

one of the best places I've ever worked.

I work for the XXX Airlift Squadron XX Air national guard as chief of Quality Assurance. I am full time military working normal weekdays with one weekend a month.

As a quality manager for a aircraft production facility working more than 8hrs./day is part of the job. But I work because I like my job.

Due to the nature of my employer (Gov't Contractor) supplying air service - duty hours fluctuate quite frequently from day to dqy flight departure & arrival times. Personnel can find themselves retrieving, late in the evening and scheduled back to work the following day for a early morning departure.

My largest problem is the 5:00 am shift time. I feel my company would get more out of me if I woke at a more natural time. Thank you.

I authorize overtime for myself and my employees. I very seldom authorize it and if I do, i do not like people working much because of the safety issues it presents. It's not worth having tired AMTs working on multi-million dollar aircraft. Its' not fair tot the passengers that put their trust in us.

Overtime with my supervisor is generally expected when required, but not mandatory. Personally, i see overtime as opportunity. I feel safety is a primary concern of my employer and would not be compromised by excessive workloads. Company policy forbids working more than 12 hours in any one day. Maybe regulation would be needed for companies without a stated policy, but not forced on a company that already has a policy.

I am a tech. Rep. For my company and as such, less than 25% of my work is actual hands on. Most of it is spent in my office, consulting or overseeing a particular operation. I also travel frequently and because of that I just sit on a plane or in an airport most of the day.

An additional 10+ hours are spent each week in preparation to perform duties as maintenance instructor.

Flight Crew, Pilots & Flight Attendants have duty times. There live depends on the AMT to provide a safe product. When will the DOT & FAA mandate a duty day for us.

I'm in management.

I would like to see the company allow me the shorten my work week from 4 to 3 day week to provide 24 hr. coverage on weekend.

(6.3) Most of time we sign up for OT.

I hold a Professional position as a Regional Sales Manager for XXX, therefore my hours greatly vary as I travel on a regular basis. I no longer work as a Technician. I work the number of hours to get the job done - I am only expected to work 40 hurs/week, but I never do.

I work for a corp. flight dept. Hours range frm early mornings to late. Corp. flight Dept. do not have the luxury of scheduling hours, you are required to be there. This could sometimes cause long days and several day's on with no time off.

I work with people who average 50 hrs per week. Late, early, they will work it. I don't want it unless its hard maint., not line departures. If I can find work all day, I will keep working 8 hours. Even paperwork, that's enough, It will tire me out. Some people work AM&PM and try to "coast" all day long, for the big payoff. 15 years ago I avg. 50 hours per week. Because no one else would usually work, junior man, etc.

I am a retired Elec. Engr. Who got his A/P going to night school in 1994. I am only interested in part-time work.

I work in the corporate world where one's time has to be flexible in order to accomplish any work necessary.

From Eastern Airlines recap source days (1965-1971) rotating shifts are fairest for Jr. vs Sr. employees, but physiologically worst for all; perhaps 1/3 mechanics went all overtime they can get double shift plus. Officially union against it but union stepping it would get too many members mad at it. An Eastern Supervisor told me 1 1/2 time costs the company as student time (with fringe benefits) as after 40 hrs, instead of paying benefits, company pays it directly to employee.

I basically set my own time. I do not work on Saturday, and I do not work overtime.

Small shop owner since I am management & labor management always wants.

I work for my self so I put in whatever is required.

Duty time revolves around aircraft. Done time equates to more work. Aircraft drive. Duty time and off time. Buy pay remains the same.

Some of my co-workers choose to work long hours, which surprises me because their work output becomes rather poor.

With reduction in force,downsizing, there is no other way to meet organizations goals/milestones without working 10 hr. days. I only charge for 8hr day.

I see many shop where they are under staffed and asking employees to work so many hours they are exhausted. I feel this leads to poor quality in workmanship.

This job is less hours than my last. I would work between 60 & 70 hours 6to7 days a week. Usually 4 days off a month. So I looked for a job with less hours on purpose.

I currently work full time in maintenance and part time for the flight department. However our employer does not pay hourly and therefore we do not receive compensation for the extra time we put in that is scheduled and expected of us.

When younger, low pay requires you to be willing to wrks lots of overtime. Thank God I don't now have to rely on O.T. to survive. Age does make it easier to say No to O.T. *There should be requirements for crew rest for maintenance folks. Working 16-24 hours is not safe for anyone.

Q4.4 Adjusted start times to....

I own my own Repair Station business so I work much longer hours than a regular aircraft mechanic. I can't just go home at 5:00, I have to make sure everything gets done on time.

Q2.4 Thursday - 7:30 AM -- 5:30 PM

I work a 6 day on 2 day off RDO starts differ from week to week. None of my co-workers like the 6-2 day RDO Sked. We are trying to get it changed, but the company insists they must keep 60% of the workforce active on the weekends. Personally I think RDOs are counter productive and cause undue stress at home.

Q4.4 Varies as to aircraft maintenance needs and owners return to service. Present job, I work for a small FBO. We are a 2man operation for both maintenance and flying. I'm retired from Boeing C.A. seattle. My working part time keeps my skills and knowledge up to date.

This survey doesn't really apply to a lot of people like me. I'm self-employed in a one man shop and work 7 days a week. (You should have included a SSAE most people might not take the time to address an envelope an place a stamp on it, just because the FAA wants the information

On call for inspection and repair, teaching new tech's (A&Ps) the things no longer taught in school -- do not think that I/we can keep this up much longer.

Q4.4 Stayed late to finish projects and wait for customers/The stresses involved in aircraft maintenance and repair require competence, both self and actual. Often the relationship between business owner/pilots and maintenance personnel is adversarial. Respect and understanding of job requirements is missing. Pay differences are often outstanding if not ludicrous.

I am the chief Inspector/Director of Inspection (management) There are few (if any) in my company that are qualified to do my job. I work until the job is done whatever it takes.

As a one person shop I work when I want and on the type A/C I want to.

I feel like I am not the typical inspector in my dept. Most will work all the overtime they can, at times 70 hrs per week. (The saturaton time) 4 days off per month is nuts "We can work 24 hours per day" but have to have 4 days off and then some have used their sick leave to get days off for overtime.

I am manager at a small FBO/Repair Station. My job is to get work finished. I have more responsibility than I desire, and much less pay than I would like. Upper management applies pressure to work more and produce more efficiently without regard to quality of life issues or compensation issues. This isn't an easy way to make a living.

Q 3.5 weekend, Sat 6-4:30, Sun 6-4:30/I work Mon-Fri as a Q.A. Inspector on 2nd shift Sat/Sun I work airframe, 6-4:30, when overtime is available.

If I had a choice I would prefer to work a scheduled 10 hr day on 3rd shift. This would allow for a 3 day weekend. And a healthier transition from a night routine to a day routine with my family. (One extra day on your weekend to allow for a night/day transition then two days for a normal "day" routine)

Q2.4 Or whenever a plane is dispatched, sometimes 4 to 5:00 am./Q3.5 I launch and recover aircraft (repair) whenever they fly. No set time./ I am a corporate maintenance technician and I am basically on call 24 hours a day. When an aircraft is broken I must stay until it is repaired. My fatigue level, or lack of rest has never seemed to be a factor to the chief pilot(s). There has always been said and unsaid pressure to get the aircraft back in service. The pilots have always been concerned over their duty times. Many times I've worked when I felt I was too fatigued.

12 A/C in "fleet" Overtime is manipulated to minimum by deferral of minor discrepancies til 'inspection'. Looks good cost wise.

I am a structural mechanic at XXX refurbishing and modification 707 aircraft. I also have my A&P.

We have 4 technicians who work 2 to a shift at which is rotated every week 5 - 2:30 and 11:00 - 7:00 with always a couple of hours extra work

I am very aware of what sleep deprivation can do to my judgment and always make sure I get enough rest regardless of the demands made on me by my superiors. Safety is always of utmost importance to me.

My hours vary due to the work we do. (Flight test). And road trips. 40 to as high as 100 hrs per week for as long as we are on the road.

Safety is an issue! Need more technicians. Need more pay for experienced people.

Most overtime is Sat and Sun 8-10 hours a day

Q3.7: 50 unpaid/My position in supervision so that is why I work 10 hour days.

I work 3 weeks swing shift 3 PM to 11:30 PM with Saturday and Sunday off then 3 weeks day shift 5 AM to 1:30 PM or 7 AM to 3:30 PM with Wednesday and Thursday off --depending on flight schedule.

NC

FBO, work until aircraft flyable quite often. People land they are buckle ? Till they can go. There stuck otherwise can you do that to people?

Section 1: Location - Office.

Would like to work longer shifts, but fewer days per week.

I am the exception in regards to schedule due to my ground safety responsibilities.

We need day shift. Starts at daylight, end at daylight.

Rotating days off. Three days on, three days off. Ten hour days. Works out real good with lon commute.

Employees with children; especially small children or infants, are particularly vulnerable to sleep & meal deprivation and disruption.

Today's Management is aligned to do more or equal work with fever employee's.

We have two mech. Working on two Falcon 20-5 aircraft. Our hands are full.

I am on 24 hour call with a pager and cell phone that never get turned off. I get paged around the clock - weekend/holidays included. I would like to see this industry set duty times for maintenance & line personnel.

See full page typed comment on reverse of survey

A/C mechanics get on the average 1/5 the way (difficult to read) of a auto mechanic. Therefore long hours and harsh treatment by owners and others are tolerated to stay employed and put food on the table. We are often required to do two or more man's work with only one man and forced to cut corners to make it work.

Several of us are mechanics and flight engineers so we usually work a lot of overtime while traveling and are gone on several weekends.

In most cases the mechanic or team on a job usually stays on the job thru completion. Most of the work is A.O.G. needing immediate attention.

I am management for my company. Times vary according to what I have going on and where.

I have previously worked rotating shifts and I will never do so again even if it means I have to quit my job!

Four 10-hour work days would be optimum!

Due to the company farming out our work, I haven't had any O.T. for around 6 months -- I like to work O.T. and try to work it, when the work load at work demands extra time for the job to be done, on time. I feel that I put out a quality product for XXX and am upset when XXX allows other businesses to do my work. The work returned from farm outs is usually not as good as the employees of XXX can do the work.

Frequent shift, days off, and work hour changes tend to disrupt things at home. The stress accompanying that disruption is usually reflected in the work place. Offering stable work hours to those who need or desire them would take a lot [of] stress out of the work place. [respondant never indicated on survey that he had RDOs or rotating shifts]

I will not voluntarily work any overtime until our contract is settled.

Thanks.

RDO suck.

To many aircraft are going over-seas for maintenance. Being an A&P, my job is being jeopardized. Its taking money out of my pocket. 40 hour work week is the same, but overtime is being cut way back because of aircraft going overseas. We need to protect the A&Ps. Keep the work in the U.S.

Need to stop overseas [cannot read word] maintenance. Before we start losing ACFT at the rate they do over there you can't cut corners the way they do and fly safe ACFT.

Shift work is hard on family life. As you can see by question on marital status - I am divorced now. We call it Airline induced divorce syndrome.

Need more money.

Management is considering changing to rotating days off for everyone. This is something I would not welcome.

What else can be said about working 3rd shift except that God created night for rest!

Overtime figures reflect when overtime was available. Third shift workers generally rearrange their sleep schedules on their days off. This can affect work performance, but should be expected by the employer. Third shifters sacrifice part of their life by working abnormal hours. They should be compensated for it. Thank you

Re: sleep -- I sleep at night

I would prefer a 10 hour workday and longer weekend. Less time on the road.

Re: sleep -- work III shift/sleep different times. We are working IIIrd shift - we are constantly changing from daytime sleep to trying to fit in w/our families on our days off - Need to go to a 4-10 hr. wk week 4 graveyard shit [sic]

None.

Q2.4: Day shift. End of Q comment: Get rid of 3rd shift, it's a real hassle and very stressful on myself and other co-workers. Nights were made to sleep. Or make 3rd shift (4-10 hours a week working program) so that you would get enough rest.

AA Already has a policy where you are not to work 30 days without four days off and we are required to not work beyond this even if asked.